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THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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VOL. III. JANUARY-FEBRUARY, 1909. No. 1

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PROGRAMME

Toronto

March 9.—Some Simple Problems of Vision,
J. R. Collins.

March 23.—The Winds of the Globe,
R. F. Stupart, F.R.S.C.

April 6.—An Astronomer in Spain,
Prof. S. A. Mitchell, Columbia University.

April 20.—Comets and the Computation of their Orbits,
Prof. A. T. De Lury, University of Toronto.

Ottawa

March 11.—The Electron Theory of Matter,
Prof. H. T. Barnes, McGill University.

March 25.—Convection as a Factor in Stellar Variations,
R. E. De Lury, Ph.D.

April 1.—Maps and Map-Making in Canada,
J. White, F.R.G.S.

April 15.—Gravity at Sea,
Otto Klotz, LL.D.

April 15.—The New Single-Prism Spectrograph,
J. S. Plaskett, B.A.

April 29.—The Tides,
W. Bell Dawson, F.R.C.S.

Peterborough

March 9.—Journey to Star Land,
G. Parry Jenkins, F.R.A.S.

March 23.—The Astronomy of Tennyson,
John A. Paterson, M.A., K.C.

April 6.—Phenomena of the Solar Photosphere,
Rev. Dr. Marsh, F.R.A.S.

April 18.—The Astronomy of the Pyramids of Egypt,
W. R. Warner, Cleveland, O., U.S.

Hamilton

The following will deliver lectures during March and April, but the dates and subjects uncertain when going to press:—

R. F. Stupart, Meteorological Observatory, Toronto.

Professor S. A. Mitchell, Columbia University.

Rev. J. J. Morton, Hamilton.

Rev. Father Rosa, University of Niagara.

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REVIEW OF THE SOCIETY'S WORK

BY THE PRESIDENT

THE beginning of 1908 marked the completion of the eighteenth year in the history of this Society as an incorporated body. From March, 1890, until May, 1900, it was known as The Astronomical and Physical Society of Toronto, when its name was changed to that of The Toronto Astronomical Society, and three years later, to that which it now bears.

With the opening of the present year a fresh start is made, as the Society begins its work under a new constitution.

As astronomical organizations were being formed at various centres throughout the Dominion steps were taken, during the Presidency of my predecessor, towards the consolidation of these centres under the charter of The Royal Astronomical Society of Canada, thus giving to the Society a national character. This movement received the generous support of the Dominion Government, and I am pleased to say that a constitution has been framed which is acceptable to all; and a future of increasing membership, and of a wider usefulness is confidently anticipated.

TORONTO.

At Toronto twenty meetings were held last year, at which the following addresses and papers were presented :—

Progress of Astronomy and Astrophysics during 1907	Dr. C. A. Chant.
The Spiral Nebula Hypothesis	
Stellar Motions	A. F. Miller.
Corrections Applied to Astronomical Observations—A series of three lectures on Parallax, Refraction, and Aberration	Prof. A. T. De Lury.
Ancient Ice Ages	Prof. A. P. Coleman.
Myths and Fancies of the Milky Way	W. J. Wintemberg.
Star Magnitudes	J. E. Maybee.
Sir William Herschel	J. T. W. Claridge, M.A.
The Sun's Motion in Space	W. H. S. Monck.
The Limits of the Universe	
The Optics of the Telescope	J. S. Plaskett, B.A.
Effect of Atmospheric Pressure on the Earth's Surface	F. Napier Denison.
How a Planet is Weighed	John A. Paterson, M.A.
Art and Astronomy	
Comets	R. Stewart Muir.
The Determination of Latitude	Prof. Louis B. Stewart.

OTTAWA.

The report of the Secretary of the Ottawa Centre shows that steady progress has been made in every department during the past year, which has been a most successful one.

The attendance at the meetings has increased, and a general interest is being aroused in astronomical subjects.

In the course of the year sixteen meetings were held, those in the evening being devoted chiefly to illustrated lectures of a more or less popular character, while the papers read at the afternoon gatherings were of a more technical nature, dealing largely with original work performed at the Dominion Observatory. These meetings are, however, open to all members of the Society, and should prove a valuable means of arousing public interest, and a national pride, in professional astronomical work in Canada.

PETERBOROUGH.

The report from the Peterborough Centre is most encouraging. The prospects for the coming year are bright, and the Centre is doing good work in arousing interest in astronomical science in its locality.

Ten meetings were held throughout the year, in addition to open-air gatherings, and general observational work among the members. The presiding officer, Dr. Marsh, has thrown his observatory open to the public, and has given various public lectures. An address delivered at Napanee was attended by one thousand persons.

It is with great pleasure that I here acknowledge, on behalf of the Society, the generous action of the Peterborough Board of Education in placing at the disposal of our members at that centre—free of charge—the chemical laboratory and class room, and convocation hall.

VICTORIA.

I regret to say that it has been found impossible to maintain the Centre at Victoria, as an organization, for the present, but a number of the members will retain their individual membership in the Society, and it is hoped that in the near future reorganization may be found possible.

HAMILTON.

It is with satisfaction I am able to announce that the association at Hamilton has been reorganized under the most favourable auspices, and has applied for permission to form a local centre of the Royal Astronomical Society of Canada. This application has been granted by the Council, and we wish our Hamilton members a long and successful career.

OBITUARY.

It is to be noted with thankfulness that the death list of noted astronomers during 1908 has not been a heavy one, although we have to mourn the loss of a revered name in the passing of

Charles Augustus Young, who died at Hanover, N. H., on the third of January, in his 74th year.

Professor Young held the chair of astronomy at Princeton University for 28 years, retiring to his New Hampshire home in 1905. When 23 years of age he became professor of mathematics, astronomy, and natural philosophy at Western Reserve College, Ohio, and nine years later received the appointment of Appleton Professor of Natural Philosophy at Dartmouth College, becoming widely known as a mathematical astronomer, observer, writer, and public lecturer.

It was as an astrophysicist, however, that he achieved his greatest fame, receiving from the French Academy the Janssen medal in recognition of his services in this field of research. Professor Young was in particular known as an authority on the Sun. The discovery of the green coronal line, of the reversing layer, and the application of the diffraction grating to solar problems, stand to his credit.

Among amateurs the death of Henry M. Parkhurst should not be allowed to pass without notice. In addition to a vast amount of other work, Mr. Parkhurst mapped the position of 100,000 stars, and his catalogue of long-period variables was published in the *Annals* of the Harvard College Observatory.

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Ham, Mrs. G. P.,	372 Shaw St., Toronto.	T
Harper, J. F.,	Bank of Hamilton, Hamilton.	H
Harper, W. E., B.A.,	Dominion Observatory, Ottawa.	O
Harrison, Henry,	Hudson Co., Bank Bldg., Jersey City, N.J., U.S.	T
Hassard, A. R., B.C.L.,	9 North St., Toronto.	T
Hastings, Miss Alma,	80 Charles St., W., Toronto.	T
Hastings, O. C.,	Victoria, B.C.	T
Hay, T. A. S.,	192 McDonnel St., Peterborough.	P
Hayter, Frederick, B.A.,	Audit Office, Ottawa.	O
Heathcott, R. V.,	Topographical Survey, Ottawa.	O
Hedley, J. Walter, B.A.,	43 McDonald St., Ottawa.	O
Henderson, A. J.,	77 St. Patrick St., Toronto.	T
Henderson, Rev. Wm.,	Frankville, Ont.	T
Herald, Charles A.,	91 Queen St., N., Hamilton.	H

Hill, John,	315 George St., Peterborough.	P
Hobson, R.,	56 Charlton Ave., Hamilton.	H
Holmes, W. C.,	Victoria, B.C.	T
Hopkins, Mrs. C.,	39 Park St., Hamilton.	H
Howell, D. J.,	Lambton Mills P.O., Ont.	T
Howell, H. Spencer,	Stonyhurst, Galt, Ont.	O
Howitt, Rev. F. E.,	104 George St., Hamilton.	H
Hoyle, G. J.,	Cannington, Ont.	T
Hubbell, E. W.,	Department of the Interior, Ottawa.	O
Hughes, Bernard B.,	6 Grace St., Toronto.	T
Hughes, James L.,	City Hall, Toronto.	T
Hull, Prof. G. F., Ph.D.,	Dartmouth College, Hanover, N.H., U.S.	T
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Hume, Dr. Rowena,	226 Carlton St., Toronto.	T
Hunter, A. F., M.A.,	Barrie, Ont.	T
Hunter, George,	Springville, Ont.	P
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Jarvis, Mrs. Percy B.,	147 Roxborough St., E., Toronto.	T
Jarvis, Percival B.,	147 Roxborough St., E., Toronto.	T
Jenkins, G. Parry, F.R.A.S.,	237 John St., S., Hamilton.	H
Jennings, Frank P.,	326 Nepean St., Ottawa.	O
Jenns, Rev. Percival.	St. John's Rectory, Victoria, B.C.	T
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Jones, Seneca,	67 Ontario Ave., Hamilton.	H
Kavanagh, Rev. I. J.,	Loyola College, Montreal, Quebec.	T
Keast, Walter, B.A.,	King Edward School, Bathurst St., Toronto.	T
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Kelley, John Douglas,	Swansea, Ont.	T
Keran, Mrs. S. D.,	148 Avenue Rd., Toronto.	T
Kerr, A. T.,	Newmarket, Ont.	O
Kimpe, M.,	Edmonton, Alta.	O
King, Mrs. W. F.,	127 Gloucester St., Ottawa.	O
King, W. F., C.M.G.,	Director Dominion Observatory, Ottawa.	O

Kirschmann, Professor A.,	University of Toronto, Toronto.	T
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Labbe, J. H.,	Dominion Observatory, Ottawa.	O
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Law, G. L.,	30 Rolph St., Ottawa.	O
Lee, Lyman,	Canada Life Bldg., Hamilton.	H
Lewis, Mrs. (Rev.),	421 Stewart St., Peterborough.	P
Lewis, J. L.,	*Herald*, Hamilton.	H
Lindsay, Stanley,	462 Sherbrooke St., Montreal.	T
Livingston, Rev. H. G.,	William St., Hamilton.	H
Locheed, J. A.,	148 Markland St., Hamilton.	H
Low, A. P.,	Geological Survey, Ottawa.	O
Lowry, S. W.,	Peterborough.	T
Ludewig, W. R.,	Care of J. A. Brashear Co., Pittsburg, P.A.	T
Lugrin, L. C.,	Editor *The Colonist*, Victoria, B.C.	T
Lyman, Walter E., B.A.,	Mechanics' Building, Montreal.	T
Macara, J.,	Dominion Observatory, Ottawa.	O
Macdonald, Wm. A., M.B.,	8 Bloor St., E., Toronto.	T
Mackenzie, A.,	Campbellton, New Brunswick.	O
Mackenzie, Douglas S.,	Gov. Telegraph Service, Dawson City, Yukon.	O
Mackie, F. H.,	Dominion Observatory, (care of Alaskan Boundary Commission), Ottawa.	O
Macklem, Rev. Provost,	Trinity College, Toronto.	T
Manley, Mrs. M. M.,	Meaford, Ontario.	T
Marr, John,	220 Pacific Ave., West Toronto.	T
Marsh, Rev. D. B., Sc.D., F.R.A.S.,	Springville, Ont.	P
Martin, John S.,	Deer Park, Toronto.	T
Mason, Miss L. M., M.A.,	27 Admiral Rd., Toronto.	T
Matheson, H.,	Geological Survey, Ottawa.	O
Matheson, Prof. J., M.A.,	Queen's University, Kingston.	T
Maybee, J. E., M.E.,	103 Bay St., Toronto.	T
McArthur, J. J.,	459 Gilmour St., Ottawa.	O
McCurdy, A. W.,	Victoria, B.C.	T
McDiarmid, F. A., B.A.,	Dominion Observatory, Ottawa.	O
McDiarmid, S. S.,	Vancouver, B.C.	O
McDougall, A. H., M.A.,	286 Kent St., Ottawa.	O
McEachren, James,	148 Mutual St., Toronto.	T
McElhanney, W. G., B.A.,	119 Eighth Ave., W. Vancouver.	O
McElhinney, Capt., M.P.,	252 Lisgar St., Ottawa.	O
McFall, W. A., M.B.,	168 Spadina Ave., Toronto.	T
McFarlane, J. B.,	153 Cumberland St., Toronto.	T

McGregor, Sir Wm.,	Gov. Newfoundland, St. John's, Nfld.	T
McKay, E. B.,	Surveyor General, Victoria, B.C.	T
McKay, A. C.,	Chancellor McMaster University, Toronto.	T
McKune, F. B.,	179 Herkimer St., Hamilton.	H
McLaren, John I., Mayor,	272 Aberdeen Ave., Hamilton.	H
McLean, Henry,	2 Wellington St., Brantford, Ont.	T
McLeish, J., B.A.,	Geological Survey, Ottawa.	O
McMilan, W. G.,	64 Howland Ave., Toronto.	T
McWilliams, E. N.,	472 Sherbrooke St., Peterborough.	P
Mellon, Gordon W.,	125 James St., S., Hamilton.	H
Meneilley, Miss J.,	31 Harbord St., Toronto.	T
Merrishaw, Mrs. F. R.,	376 Markham St., Toronto.	T
Miller, A. F.,	280 Carlton St., Toronto.	T
Miller, A. P.,	Transcontinental Ry., Vermilion, Ont.	T
Mills, Harry P.,	19 Winchester St., Toronto.	T
Milne, C. G., B.A.Sc., C.E.,	237 Victoria Ave., N., Hamilton.	H
Mitchell, C. W.,	428 Lewis St., Ottawa.	O
Moore, E. P.,	Burlington, Ont.	H
Moore, Isaac E.,	Rothsay, N.B.	T
Morgan, Ernest,	20 Alason St., Hamilton.	H
Morton, Rev. J. J.,	39 Park St. S., Hamilton.	H
Moss, Lady,	547 Jarvis St., Toronto.	T
Motherwell, R. M., M.A.,	Dominion Observatory, Ottawa.	O
Mountain, G. A., C.E.,	Chief Engineer, Railway Commission, Ottawa.	O
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Murray, Wm.,	Athol Bank, Queen St., S., Hamilton.	H
Musson, W. Balfour,	22 Park Rd., Toronto.	T
Near, W. Percy, B.A.,	St. Mary's, Ont.	T
Neill, A. T.,	City Hall, Hamilton.	H
Nelles, D. H.,	Dominion Observatory, Ottawa.	O
Nelson, H. M.,	303 Frank St., Ottawa.	O
Nicholson, A. R.,	Victoria, B.C.	T
Nolte, F. W.,	Victoria, B.C.	T
Norris, I. T.,	564 Rideau St., Ottawa.	O
Northwood, Miss M. A., B.A.,	330 Chapel St., Ottawa.	O
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Odell, J. W., B.A.,	Cobourg, Ont.	T
O'Farrel, F.,	Geological Survey, Ottawa.	O
Ogilvie, Noel J.,	Dominion Observatory, Ottawa.	O
Ogilvie, William.	27 Nepean St., Ottawa.	O
Oliver, Cyrus P.,	55 Fairmount Ave., Hamilton.	H

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Parker, T. H., B.A.	Dominion Observatory, Ottawa.	O
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Patterson, A. W.,	358 Stewart St., Peterborough.	P
Payne, J. L.,	Dept. Railways & Canals, Ottawa.	O
Peagam, H. E.,	254 Yonge St., Toronto.	T
Peers, Miss Brenda,	92 View St., Victoria, B.C.	T
Penson, S. R. G.,	19 Canada St., Hamilton.	H
Perkes, Albert E.,	82 Ashley St., Hamilton.	H
Petry, Charles B.,	61 Isabella St., Toronto.	T
Phillips, John,	125 Victor Ave., Toronto.	T
Plant, W. H.,	278 Borden St., Toronto.	T
Plaskett, J. S., B.A.,	Dominion Observatory, Ottawa.	O
Plaskett, T. S.,	489 Manning Ave., Toronto.	T
Playel, Charles A.,	4 Elmgrove Ave., Toronto.	T
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Porter, J. S.,	Stayner, Ont.	T
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Ptolemy, R. A.,	King St., E. of Arthur, Hamilton.	H
Pugsley, E., B.A.,	Elora, Ont.	T'
Rainboth, G. C.,	Aylmer, Quebec.	O
Redman, Lawrence V., B.A.,	Trinity College, Toronto.	T
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Richard, Louis N.,	Geological Survey, Ottawa.	O
Ridout, George,	77 York St., Toronto.	T
Ridout, Captain J. G.,	103 Bay St., Toronto.	T
Robert, J. A.,	Geological Survey, Ottawa.	O
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Robertson, H. S., B.A.,	Hartley Hall, Columbia University, New York.	T
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Robinson, W. A.,	34 Charlton Ave., E., Hamilton.	H
Roger, G. M.,	309 Park St., Peterborough.	P
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Ross, Miss Anna,	Strassburg, Sask.	O
Ross, A. H. D., M.A., M.F.,	University of Toronto, Toronto.	T
Ross, Charles C.,	70 Fourth Ave., Hintonburg, Ont.	O
Rothwell, Miss Lina,	390 Daly Ave., Ottawa.	O
Rothwell, Miss Ruby M.,	Carisbrooke Apartments, Bank St., Ottawa.	O
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Rudlen, George W., B.A.,	Sault Ste. Marie, Ont.	O
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Saint-Cyr, Arthur,	Topographical Survey Br., Ottawa.	O

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Scott, J. R.,	10 Ruth St., Hamilton.	H
Seymour, H. L.,	15 Patterson Ave., Ottawa.	O
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Shepard, Hon. J. M., M.P.P.	American Consul, Hamilton.	H
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Smith, Professor Goldwin,	The Grange, Toronto.	T
Smith, Larrett Goldwin,	Smith, Rae & Greer, Toronto St., Toronto.	T
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Stewart, Elihu,	509 Coristine Building Montreal.	O
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Stewart, Robert,	220 MacLaren St., Ottawa.	O
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Stewart, W. J.,	Hydrographic Survey, Ottawa.	O
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Tate, Charles,	186 Manning Ave., Toronto.	T
Taylor, Wm.,	China Inland Mission, Kiukiang, China.	T
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Torin, James,		T
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Tribble, J. N., B.A.,	Audit Office, Ottawa.	O

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Unsworth, Miss C.,	89 Charlton Ave., Hamilton.	H
Upton, Charles,	Homebush, Instow, N. Devon, Eng.	T
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Waite, E. B.,	4217 Ellis Ave., Chicago, Ill.	T
Walker, D., B.A.,	Brock St., Peterborough.	P
Walker, Miss I. M.,	116 George St., Hamilton.	H
Wallace, R. M.,	489 Church St., Toronto.	T
Wallis, J. D.,	336 Laurier Ave., W., Ottawa.	O
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Wenger, C.,	Victoria, B.C.	T
Werry, F. W. O., B.A.,	Saranac Lake, N.Y.	O
Wetherbee, Weston,	Albion, N.Y., U.S.	T
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Wilson, W. J.,	Geological Survey, Ottawa.	O
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DEVELOPMENT IN THE STELLAR UNIVERSE

By W. Balfour Musson

(PRESIDENT'S ADDRESS, ANNUAL MEETING, JANUARY 12, 1909).

DR. Sterling, the Scotch philosopher, has somewhere said that what is peculiarly Human is to perceive the apparition of the Universe, and to interrogate it.

None has perceived this apparition in broader outline; none has interrogated it more assiduously than the astronomer, and it shall be my endeavor this evening to indicate, in one of its aspects, the vision which he has seen, as well as to review briefly some of his methods of interrogation.

When man, becoming interested in the world about him, first turned his eyes to the celestial vault, he beheld it inlaid with myriad twinkling points of light, silently presenting a riddle which must have appeared to him forever hopeless of answer. Within the lifetime of the present generation that riddle has been read with a measure of success scarcely conceivable half a century ago, and although we are only at the beginning and investigation is surrounded with difficulties at every step, still a little ground is gained year by year, and, though the final solution remain beyond the reach of finite intelligence, further conquests will surely be made.

In stating the problem I cannot do better than to put it in the words of Herbert Spencer, a philosopher whose speculations, in view of the striking confimation afforded them by subsequent research, scarcely appear to receive, in astronomical literature at least, that attention which they would seem to deserve.

"Given a universe," says Spencer, "composed of a fixed quantity of matter and motion existing in harmony with known laws, to trace the process by which the cosmos evolved from its primal to its present state.

"The persistence of force is a philosophical necessity, without it there would be chaos not a cosmos.

"Viewed in the light of the nebular theory, of the law of gravitation, and of the doctrine of the conservation of energy, the universe is the result of one process—*the redistribution of matter and motion.*" In other words, the universe is viewed not as a "manufactured product," but as a "dynamic process," and phenomena appear no longer as unconnected facts, but as links in a great chain.

It is the law, or laws, governing the redistribution of matter and motion which is to be the subject of our inquiry.

In his address before the British Association at Leicester (1907) Sir David Gill said: "Evidence upon evidence has accumulated to show that nebulæ consist of the matter out of which stars have been, and are being, evolved. . . . . The fact of such an evolution, with the evidence before us, can hardly be doubted. I most fully believe that, when the modifications of terrestrial spectra, under sufficiently varied conditions of temperature, pressure, and environment, have been further studied this connection will be greatly strengthened."

Evolution is not merely a growth, but a development of something from something different. An organism not only is born, reaches maturity and dies, repeating itself *sui generis* indefinitely, but in process of time a type is produced essentially different from the preceding type. This process has been associated with a change from the simple to the complex, and the statement is equally valid whether applied to organic or to cosmic evolution—from a simple homogeneous nebula to a complex sun, with its nucleus, photosphere, chromosphere and corona, its faculæ, spots and protuberances.

Heretofore the advocate of stellar development had been obliged to base his deductions upon a primeval nebula, but more recently the discoveries of the chemist and the physicist have led to the daring conception that it may be possible to push the genesis of the physical universe one step farther back, and to postulate the ether itself as the substance from which nebulæ

have birth. Is it too much to hope that some future President of this Society may address you upon *The Evolution of a Nebula from the Ether?*

When referring to recent advances in spectrum analysis, during the course of an address before the Royal Instiution a few years ago, Prof. Thomas Preston used the following words: "These observations lend some support to the idea so long entertained merely as a speculation, that all the various kinds of matter, all the various so-called chemical elements, may be built up in some way of the same fundamental substance; and it is probable that this protyle theory will, in one form or another, continue to haunt the domains of scientific thought, and remain a useful and important factor in our progess for all time to come." And, in some supplementary remarks to a discourse on *The Ether of Space*, delivered at the same institution in February last, Sir Oliver Lodge said:

"A material unit—say an electron—is only a peculiarity or singularity of some kind in the ether itself, which is of perfectly uniform density everywhere. What we sense as matter is an aggregation, or grouping, of an enormous number of such units."

And again—in commenting upon the works of Robert Hooke: "The tacit assumption here made [by Hooke] is that the particles of the aggregate are all composed of one and the same continuous substance—practically that *matter is made of ether*; and that assumption, in Hooke's day, must have been only a speculation, but it is the kind of speculation which time is justifiying—it is the kind of truth which we all feel to be in process of establishment now."

If in the present state of our knowledge, or, if some prefer it, in the present state of our ignorance, such speculations appear somewhat visionary we should recollect that the inconceivable of yesterday has often become the commonplace of to-day. The subtlest instrument of research, if properly controlled and directed, is the imagination, and scientific theories will doubtless be in the future, as they have been in the past, valuable guides to observation and experiment.

We should not expect to find one direct and unbroken line of development obtaining in the stellar universe since astronomy, as well as biology, doubtless, has its divergent lines of evolution —has, indeed, its missing link—and we can only hope to glimpse some outline of a general process rather than of a completed theory.

First let us endeavor to trace the probable growth of a single sun from its parent nebula.

Imagine, then, in the depths of space, a homogeneous sphere of gas, losing heat by radiation, and condensing towards the centre. The original temperature of this sphere need not be great as it contains a store of potential energy equal to all demands made upon it by the evidence of high temperatures in succeding stages of development, and its luminosity may be sufficiently explained by the mean motion of all its molecules.

Were this mass of gas sufficiently rare the spectrum, theoretically, would consist of a few bright lines. Finding the brightness of spectral lines to depend upon the thickness of the stratum of incandescent gas, Zöllner deduced the principle that, "If the density of a gas decreases uniformly, the temperature remaining constant, then the number of lines must diminish until a single line survives, the position of which line, for any particular substance, would depend upon the temperature." Frankland and Lockyer experimentally demonstrated this deduction to be sound, and it appears to be abundantly verified by observation. The typical nebular spectrum consists of but three or four lines—due to hydrogen, helium, and some element as yet unknown—and in the faintest of these objects a single line only appears. As Huggins has shown that the number of lines might also be reduced by mere faintness of light the simplicity of the nebular spectrum may therefore be attributed to the rarity of the gas, and to the faintness of its light. Whether the character of this spectrum is due, in chief, to the physical condition of the gas, or to its chemical constitution, is a question for further consideration.

Nebulæ may be divided into two classes—those, like the Orion nebula, whose spectra consist of a few bright lines, and

those yielding a faint continuous spectrum, such as that of the great nebula in Andromeda, and most of the spirals.

The condition of a mass of gas such as we have assumed would necessarily be one of unstable equilibrium. Owing to radiation at the surface, followed by contraction towards the centre, and a consequent increase of internal temperature, convection currents would be set up in an endeavor to restore the thermal equilibrium. It is generally held that the temperature of a star rises as its diameter decreases, but this law can be depended upon only so long as the mass behaves as a perfect gas. Professor Schuster suggests that it is not likely to apply to the surface, or to the centre of a star, but that it is probably true for the intermediate regions.

As condensation advanced the heavier elements would gravitate towards the centre, and eventually give rise to a continuous spectrum, while the lighter gases, such as hydrogen or helium would remain at, or be driven to, the surface, where, becoming cooler, they would in accordance with Kirchoff's law produce the Fraunhofer lines. Helium being the heavier should be absorbed first, leaving hydrogen as the dominating feature in the star's atmosphere, to be modified later by metallic lines as the diameter of the star decreased, and the stirring up by convection currents became more thorough.

Let us now leave theoretical considerations for the moment, in order to examine the peculiarities of the various spectral types scattered throughout the universe of stars.

It is evident that the process of stellar evolution cannot be a subject of direct observation, since a day in the lifetime of a star may exceed the total duration of life upon the earth. It is possible, however, by a comparative study of different types of stars to form a probable history of their genesis and ultimate destiny.

To begin with the Orion, or so-called helium type, we find in the Trapezium stars a spectrum consisting only of faint lines of hydrogen and helium, and as these stars are with good reason considered to be physically connected with the nebula, there can be but little doubt that they represent the first period in the life

history of a sun. In what is regarded as a more advanced stage the lines of silicon, magnesium, and nitrogen are beginning to appear, and in *Bellatrix*, a typical example, the presence of oxygen has been confirmed. Passing onwards to a star like *Vega* we find that while helium is still represented, it is rapidly dying out. Hydrogen is becoming prominent, and oxygen and nitrogen are giving place to numerous, though faint, metallic lines.

In the spectrum of *Sirius*, the typical hydrogen star, helium has entirely disappeared, and such familiar elements as sodium, iron, magnesium, and calcium are in evidence, hydrogen absorbtion being strongly marked.

The transition from the hydrogen to the next type—the solar—is gradual but definite. When this stage is reached a profound change has occurred. The outer surface of the star has evidently cooled to the point where the metallic vapors are condensing, and falling back in showers of iron and carbon rain. An atmosphere of absorbing vapors is forming, so dense as to materially modify the character of the star's radiation, the violet end of the spectrum being so far damped as to change the predominating color from blue to yellow.

The convection currents now set up are, in all probability, violent, and the strengthening of the metallic lines is pronounced, iron alone being represented by over two thousand lines, and calcium by broad and heavy absorption. The alteration in the appearance of hydrogen, calcium, iron and magnesium—more especially the weakening of hydrogen, and the strengthening of calcium—may in fact be regarded as characteristic in the transition from a hydrogen to a solar star.

The behavior of calcium, under varying degrees of density, is so important as to deserve special attention. The relation between the line at $\lambda 4227$, and the H and K lines had long been regarded as an effect of temperature, but as this conclusion led to an anomaly when reasoning upon temperature conditions in the Sun, Sir Wm. Huggins in 1897 instituted a series of experiments which conclusively proved that what had been regarded as due to temperature was in reality an effect of density—as the

density of the calcium vapor decreased the line λ 4227 disappeared, leaving only *H* and *K* visible. This result agrees with the appearance of calcium in the solar spectrum, where λ 4227 is strong in the region near the photosphere, but decreases in intensity in the higher levels of the chromosphere where the density must be considered to be less.

Before leaving the solar stars it will be advisable to consider some of the more recent work on sun-spots, as the results have an important bearing upon a discussion of succeeding stellar types. In the past, opinion has been divided as to whether sun-spots were centres of higher or lower temperature than the surrounding photosphere, and many efforts were made, at the Kenwood Observatory, by Professor Young at Princeton, and with the 40-inch Yerkes refractor, to decide the point at issue, but with inconclusive results—felt to be due mainly to insufficient instrumental equipment. Dr. Hale, therefore, attacked the problem with the Snow telescope, and a powerful spectroscope, aided by elaborate laboratory apparatus including means for studying, under varying conditions of temperature and pressure, the spectra of metals in the arc, the electric spark and the bunsen flame. The phenomenon chiefly requiring explanation was the observed strengthening and weakening of certain solar lines when seen in sun-spots. The spectrum of iron was photographed in the electric arc, first with a large current, and then with a small current, with the result that most of the lines which are strengthened weakened, or unchanged in sun-spots were found to be also strengthened weakened, or unchanged in the lower current. The next step was to determine the relative temperatures of the vapors produced in the two arcs. This was done indirectly by comparing the spectrum of the core of the arc with that of the flame extending from it, which is at a lower temperature. It was found that the changes in the lines examined, when passing from the hot core to the cooler flame of the arc, agreed with those noted when comparing the solar with the sun-spot spectrum. It was further demonstrated that these changes persisted under conditions excluding electrical effects.

In his recent work, *A Study of Stellar Evolution*, Dr. Hale says (p. 194): "It was shown that when all electrical phenomena are excluded a decrease in temperature of the radiating vapors is accompanied by an increase in intensity of the lines that are strengthened in sun-spots and in red stars."

Experiments are now in progress which, it is hoped, will finally confirm the inference that regions of sun-spot disturbance are regions of diminished temperature. Strong independent evidence of such an inference is found in the fact that the Snow telescope has revealed in sun-spots the presence of *titanium oxide*.

In the reversing layer of the Sun oxygen exists in proximity to titanium, and the conclusion is unavoidable—unless it be admitted that pressure plays a part in the phenomenon—that the combination of these elements in the umbra of a sun-spot is indicative of a fall in temperature.

Following the solar stars in order of evolutional development is a type whose spectra are characterized by dark bands or flutings. In stars described as Type III., in Secchi's classification, the origin of these bands (which are sharply defined towards the violet) was long unknown, but Professor Fowler has now shown them to be due to titanium oxide. As stated above, Dr. Hale had discovered similar bands in the spectra of sun-spots, and it became a question of exceeding interest to determine whether, in this respect, spectra of the third type agreed with the sun-spot spectrum. *Betelgeuse* (*α Orionis*) was selected for the experiment, and a spectrograph obtained by Adams, with a total exposure of seven hours, demonstrated the idendity of the flutings with those of sun-spots. To use Dr. Hale's own words,—"The resemblance between the spectra of sun-spots and those of third-type stars is so close as to indicate that the same cause is controlling the relative intensities of many lines in both instances. This cause, as the laboratory work indicates, is to be regarded as reduced temperature."

As some doubt at first existed as to whether the bands obtained from oxide and chloride of titanium were due to the vapor of the oxide, or to the metal itself, Professor Fowler undertook

to decide the question experimentally. If the flutings were due to the element they should appear in various compounds of titanium with other elements. If due to the oxide they should disclose themselves only when oxygen was present. Decisive results were obtained—the characteristic bands were given only by the aid of oxygen.

There remains for consideration one other of the fundamental stellar types—that known as Secchi's Type IV. Spectra of this class are also marked by dark flutings, but these flutings are shaded in the reverse direction to those having their origin in the combination of titanium with oxygen, and have long been known to be due to carbon, or to carbon compounds. As none of these "carbon" stars are brighter than the 5·3 mag. the examination of their spectra in telescopes of small aperture is extremely difficult, if not impossible, and it is therefore a subject for congratulation that Dr. Hale decided to utilize the great light gathering power of the Yerkes instrument for this purpose. The results of his investigation, in which he was assisted by Mr. Ellerman, and Mr. J. A. Parkhurst, are set forth in the third volume of the decennial publications of the University of Chicago.

It was not until the publication of his second memoir in 1868 that Secchi separated in his classification these stars from those of the preceding type, and the real relation of Type III. to Type IV. is still uncertain. The line spectrum of the two classes is, in many respects, similar, but they are clearly differentiated by the character of their flutings. The slight layer of carbon in solar stars has become so dense and heavy in stars of Type IV. as to absorb to a great extent their violet radiations, and to cause them to glow with a dull red color. So marked is this change that the Yerkes refractor, on account of its violet absorption, was abandoned, when photographing their spectra, in favor of the reflector.

The spectrographs show the calcium line at λ 4227, and the *H* and *K* lines to be very conspicuous, as was to have been expected, and flutings due to cyanogen are prominent. The metallic lines are stronger than in the Sun, and several bright lines are

also visible, due probably, to gases rising above the cooler vapors. The spectrum, according to Dr. Hale, is such as might be expected from the cooling of a star like the Sun, "especially if such cooling were accompanied by the development of extensive sun-spots."

Is the strong tendency to variability in red stars due to conditions similar to those giving rise to the phenomenon of spots on the Sun? Is the appearance of such spots to be regarded as the first indication of stellar decrepitude?

In the monograph referred to the authors show the resemblance between third and fourth type stars to consist in—their red color, their tendency to variability, the close agreement in the dark line spectrum, in the suspicion that both possess lines that are widened in sun-spots, in the indication of similar physical condition, in the presence of bright lines, in their spectra, in the common possession of cyanogen flutings, and in the apparent relation of both types to the solar stars; the conclusion being that they should be classed as coördinate branches developing from Type II.

Although all intermediate types are found between II. and III., there are gaps between II. and IV., but owing to the small number of the fourth type which have been observed it may be hoped that, in time, this gap will be bridged—that the missing link will be discovered.

It has now been shown that theoretical and mathematical investigations, laboratory experiments, and the direct observation of stellar spectra, alike point to a connected sequence of change from gaseous nebulæ to planetary nebulæ, and on through helium, hydrogen, calcium and solar, to titanium oxide and carbon stars; and a more detailed discussion than is here possible would demonstrate with equal conclusivenesss that the transition from type to type is, in the main, not abrupt and such as might seem to depend upon original differences of chemical constitution, but gradual and orderly, conveying beyond reasonable doubt, the conviction that we behold on a stupendous scale the evidence of

an evolutional development, the dominating factors in which are loss of heat and increasing density, or in the definition of Spencer, an integration of matter and a dissipation of motion.

As before stated, it is not necessary to expect that advance will be along one unvarying path; environment and mass may be determining factors in a star's life history; the general principle, however, will not be affected.

In an admirable and carefully reasoned address on *The Evolution of Solar Stars*, delivered before the Royal Philosophical Society, Professor Schuster raised the question why some stars should show an exclusively hydrogen spectrum, and suggested in explanation that the first condensation had probably resulted in the rejection of hydrogen and helium, since the development of heat would increase their volume until the power of gravity was insufficient to retain them, and they would collect in adjoining regions of space, thus forming the gaseous nebulæ. Condensations of matter which have been thus purged of hydrogen might not unlikely, in some instances, form the nucleus for larger aggregations, and these, on account of their increased power of attraction, might recover and hold immense atmospheres of hydrogen gas. Is it possible that the enigmatical Wolf-Rayet stars may be thus accounted for? The place of these stars in any system of classification is at present doubtful owing to the complex nature of their spectrum which, in addition to being continuous, is strongly marked by both hydrogen emission and absorption. Campbell, when observing one of these stars (*D M* +30° 3639) on the *F* line, like a solar prominence, saw a distinct disk which, upon narrowing the slit, resolved itself into a narrow line 5″ in length. What he in reality observed was a vast hydrogen envelope surrounding the star.

According to Schuster a star might come into existence without ever having passed through the hydrogen stage, while on the other hand some stars, which may have happened to form in regions rich in hydrogen, might attract this gas beyond their power to absorb it, and thus show the hydrogen spectrum during the greater part of their history.

The influence upon the spectrum of different elements, existing side by side, is one requiring much further investigation. As is well known certain metals, such as sodium and carbon, will strongly assert themselves even when their vapors are present in comparatively small quantities. Dr. W. E. Wilson, in a paper read before the Royal Society in 1905, draws attention to the fact that a tube filled with hydrogen is incapable of producing any absorption effect when placed in the path of light coming from a source giving a continuous spectrum, and argues that hydrogen atmospheres of vast extent might still be almost transparent.

"It thus seems not improbable," he says, "that if all the hydrogen at present in the solar system were again expanded into a nebula, say with a diameter ten times the orbit of Neptune, it would then, if seen from a distant star, still give a bright line spectrum, the same as Orion now gives us."

Under such conditions the effect of sodium and other metals, which probably exist in small quantities in the Sun, compared with hydrogen, would not unlikely be invisible. The marvellous tenuity of the gases composing nebulæ is attested by the fact that in the Orion stars we are probably viewing them through millions of miles of hydrogen and helium, yet their light shows clear and distinct; and, as observed by Hale, Frost and Adams have shown some of these stars to be moving in orbits about dark companions without any appreciable evidence of a resisting medium, although they are presumably imbedded in the heart of the nebula.

We are now led inevitably to a discussion of the problem of stellar temperatures. This is a question upon which there exists considerable diversity of opinion. While there is a general agreement as to the evolutional order in which the various stellar types should be ranked, the stage in a star's history at which the highest temperature is reached is a matter of much less certainty. It is admitted that the temperature rises as condensation advances, but is the maximum attained in a star like *Sirius*, or not until the solar stage? Huggins and Young give the preference to the later, while Lockyer and Schuster favor the earlier period.

Hale regards the greater intensity of the enhanced lines as evidence of exalted temperature.

As I desire to present a general view of the subject, rather than to enter into a minute discussion of details, I shall refer very briefly to some of the considerations which have led to the opinions quoted. When we speak of the temperature of a star, as exhibited by its spectrum, we, of course, refer only to the regions yielding the radiations to which the spectrum is due. These regions in the Sun are confined to the photosphere and the vapors just above it—a comparatively shallow layer. With regard to stars in a more diffuse state, however, the spectrum may result from light originating at great depths within the mass.

As the investigations of Lane can be depended upon only when the contracting mass obeys the law of a perfect gas, caution is necessary in the application of his law to bodies of whose internal condition we know as little as we do of, as that of the Sun. Deductions based upon magnitude and color are uncertain and may, for various reasons, prove misleading; while the argument drawn from the extension of the violet end of the spectrum is not conclusive as this effect may be, in part, due to lack of absorption.

Conclusions as to temperature have also been drawn from the appearance of certain spectral lines, under certain terrestrial conditions, but here again caution must be observed. As previously observed, changes in the line λ 4227, at one time attributed to temperature, have been shown to depend upon density, and the relation of the arc to the spark spectrum has been the subject of controversy. The electric spark has been very generally regarded as possessing a higher temperature than the arc, and when the behavior of particular lines in stellar spectra resembled that of the same lines when seen in the spark spectrum, the tendency has been to place the stars yielding these lines upon a high temperature level.

When investigating the effect of the electric arc under water, however, Messrs. Eberhard and Hartmann were surprised to find that it yielded lines hitherto regarded as peculiarly characteristic

of the spark. The magnesium line λ 4481, for example, appeared as one of the brightest in the entire spectrum, being narrower and more sharply defined than when seen in the spark; and as the development of this line had been considered to be especially indicative of a high temperature the fact was one of extreme interest. It was also found that the line in question was prominent in the arc spectrum when hydrogen was present, and, further, that when viewed through a current of hydrogen, the arc gave a spectrum almost identical with that obtained under water. The conclusion drawn from these facts was that the release of hydrogen by electrolysis accounted for the alteration in the arc spectrum. It will thus be seen that it is unsafe to dogmatize upon the temperature of stars from the appearance of their spectra since, to take this single example, the presence of a hydrogen atmosphere might materially modify the magnesium spectrum.

Lockyer accounted for the absence of the metallic lines in early-type stars by the supposition that their atmospheres were too hot to permit of the existence of the molecules in which they have their origin. In such instances, however, as it has been possible to test this assumption the results do not sustain the hypothesis.

Several attempts have been made to classify the stars on a temperature basis, but such a method appears to be far from satisfactory.

We have now briefly traced a star's history from its birth from a nebula to extreme old age, represented by the red and heavy-atmosphered carbon stage, and here let us leave it to cool and gradually die out, while we return to the original nebula to inquire whether any variation of this history is probable.

It was for a long time believed that the figure of equilibrium of a rotating mass of fluid was a surface of revolution about the axis of rotation. Jacobi showed, however, that an ellipsoid of three unequal axes, rotating about the shortest axis might be in a state of equilibrium; and the further investigations of Poincaré demonstrated that when the oblateness of such a figure became two-fifths it would lose its stability, and a new species be de-

veloped—that of the pear shape—which would eventually separate into two masses, comparable in size. Mr. Jeans, of Cambridge, extended the investigation to the action of a gaseous mass, with analogous results, although factors of such difficulty entered into the calculation as to leave it incomplete.

It is perhaps unwise to rest too securely upon the visual appearances of nebulæ, until it is certain that we have obtained a complete picture of the object under observation, and a correct knowledge of the plane in which it lies. Increased light-gathering power, whether by enlargement of the telescope, or greater length of exposure of the photographic plate, has often altered considerably our conception of such an object. Nevertheless drawings of Webb's planetary nebula *D M* +41°, 4004, and that known as *N.G.C.* 7026 appear little less than visual demonstrations of the process of development treated theoretically by Jacobi, Poincaré, and Darwin.

Dr. Geo. H. Darwin, as is well known, worked out the effect of tidal friction upon two bodies in a semi-fluid state, revolving about their common centre of gravity. Tracing the history of the earth and Moon back from their present separation of 240,000 miles, he showed by mathematical calculation that there was a time when the day and month were equal, being only four or five of our present hours, and the two bodies were separated by a few thousand miles. Thus the theoretical conclusions of Poincaré and Darwin met, and a new chapter opened in the history of stellar evolution.

The fact that some of the double stars were physically connected, and formed true stellar systems, was announced by Sir Wm. Herschel in 1802, but unexpected revelations followed the introduction of the spectroscope into this field of research, and observers were not slow in taking advantage of the new weapon placed in their hands. Since Pickering's discovery in 1891 that *β Lyræ* was a double system, the components of which revolved in a period synchronizing with its variation in brightness, the study of binaries has excited renewed interest.

The researches of See and Roberts afford the most striking confirmation of the mathematical deductions. Dr. See has drawn attention, in particular, to two characteristics of visual binary systems which might have been safely predicted on the assumption that they had their genesis in one original mass—namely, that the components are always comparable, and frequently equal, in mass; and that their orbits are highly eccentric. This eccentricity of orbit, Darwin has shown, as the result of tidal action, to have been inevitable.

See published his first volume a little over ten years ago, and has since been occupied with a critical examination of the comparative eccentricities of visual and spectroscopic binaries, being confident that the result will afford valuable information regarding the evolution of these systems. His latest observations have appeared during the past year and show that, after excluding all visual objects, there remain 30 spectroscopic systems, giving an average eccentricity of 0·22, in some instances the orbits being practically circular, and the period under 24 hours. There are some 80 orbits of visual pairs which have been fairly well determined, and which show an average eccentricity of 0·50, or more than twice that of the spectroscopic stars.

The result of investigations carried out during the past decade is therefore a remarkable confirmation of Darwin's theory.

Dr. Alexander Roberts has had under observation at Lovedale, South Africa, several close pairs whose elements are of the highest interest, but time will not permit of more than a hasty résumé of his results.

V Puppis is a system whose components, nearly equal in size, are separated by only a tenth of either of their diameters, the orbit being but slightly elliptical, and the calculated diameters of the components so enormous as to leave no other conclusion than that they are "vast gaseous masses." Dr. Roberts believes the birth of these twin stars to have occurred not over 400,000 years ago—in other words, they are mere stellar infants.

One of the most remarkable systems known is that of *R² Centauri*, in which the two stars are in actual contact, revolving in a

period of about 14 hours 32 minutes. The typical system of this class, *β Lyræ*, has a period of 12 days and from 21 to 22 hours, and possesses extraordinary interest from the fact that observation shows the companion stars to be receding one from the other. In 100 years the amount of this recession is calculated to have been 50,000 miles.

In *V Vulpeculæ* the calculated density is only 0·00002, while the period is 75 days. In reality it consists of, to use Dr. Roberts' own words, "Two vast nebulous orbs, the protoplasm of worlds in the making, circling round each other in measured motion."

The shortest period given is that of *U Pegasi* which is under 9 hours. Have I made the bearing of these facts clear? Mathematical investigation has shown the fate of a rotating fluid mass under certain conditions to be the evolution from a spherical to an egg-shaped figure, and from that, as rotation increases, to a pear or dumb-bell form leading to a gradual separation into two parts, comparable in size. These two bodies would revolve at first in a circular orbit, but under the influence of tidal action would gradually recede from one another, and in process of time the orbit would become more eccentric. The density of the bodies, at first that of a gas, would gradually increase, and each star run its separate course, and pass through all the stages of its life-history.

Observation has shown the components of spectroscopic binaries to be of exceedingly low density, to move in nearly circular orbits of short period, and to be only slightly separated, while in one case at least they are shown to be receding. In visual pairs the orbits have become highly eccentric, and their density is at least doubled. Further comment upon the close agreement between theory and observation is unnecessary.

Another question now presents itself; in binary systems we are dealing with two stars which must be of the same age, should we expect, then, to find them yielding spectra of a similar type? Undoubtedly yes, if they were of equal mass. Enough has been said, however, to show that a star's mass may be a factor of even greater importance than temperature in bringing about those

spectral changes which are held to indicate its spectral development. Whether mass exerts an accelerative or a retardive influence upon such changes has been a question much debated. We have seen, however, that there is every reason to conclude that the components of double star systems are not very different in mass. How, then, are the color contrasts in the members of such systems to be accounted for, and why should the companion of Algol be dark? In *Problems of Astrophysics*, the late Miss Clerke says:

"A doubt arises whether the shining of suns depends solely upon temperature; for gradations of cooling cannot possibly account for the abrupt contrasts of luminosity met with in mutually revolving globes. Irresistibly the hypothesis presents itself that, among the varieties of the cosmos, there may be a multitude of bodies conditioned in most respects like suns, but which never attained to the possession of a photosphere, and have consequently remained imperfect radiators."

We might also expect to find great eccentricity of orbit accompanied by advanced spectral type, since both elements may be held to indicate a late stage in life-history. Sufficient data is not yet available to permit of a categorical reply to such questions.

There is no means of estimating, even approximately, the immense æons represented in the history of stellar development; the story, we cannot doubt, is written upon the vast page of the universe, and the astronomer, by severe and long continued toil, has caught some inkling of its meaning, but even imagination fails to focus that story upon the retina of the mind. Darwin thinks one thousand million years not to be an extravagant estimate of the age of the Moon.

There is one known line of development not covered by either of the histories which we have traced. The solar system, as far as we know, is unique. In the multiplicity of the bodies composing it, and in the small ratio of the sum of their masses to the central sun, we know of no counterpart to it in the universe. Such systems there may be, but their existence is purely conjectural. The history of such a system must be one of entrancing

interest, and the effort to reconstruct it has challenged the highest powers of the mathematician and the theorist. It is unnecessary here to review the well known hypothesis of Laplace, suffice it to say that while it may be retained with certain modifications, it can scarcely survive in the form in which it was originally put forth by its great founder. The most serious objection to Laplace's theory is probably the small moment of momentum at present possessed by the solar system, which fact does not harmonize either with the theory, or with dynamical law.

Professor Moulton sees in spiral nebulæ the origin of systems composed of a central sun surrounded by a number of planets, and claims to have mathematically demonstrated that his theory removes most of the anomalies of the Laplacian hypothesis. He postulates two single bodies approaching one another at great velocities, and either grazing or passing in close proximity; the tidal disturbance thus established causing great outbursts of heated matter which would form the future planets, revolving about one of the original bodies.

Whether a system so formed could present, at the probably enormous distances of the spiral nebulæ, a picture comparable in size to the photographic representation of such objects must be left for others to determine.*

* Dr. Isaac Roberts considered that the "breaking up, by collision, of two solar systems, viewed at the distance of Sirius"—which has a parallax of 0·38″ = 8·58 light years, would produce a result "too feeble in its light intensity to imprint more than a small splash on a photographic plate."

What, then, would be the mass of two single bodies capable, by their impact, of forming such an object as the spiral nebula M. 51, containing within its convolutions more than 50 stars, some of which are separated by over 8′ of arc.

Mr. Collins has kindly called my attention to the observations of Professor Bohlin, of Stockholm, made in the attempt to determine a parallax measurement for the Andromeda nebula. If the result of these observations—0·17″ is correct, it would indicate that the distance of this nebula from the Sun is some 17 light years, and that the diameter of the major axis is 800 times that of the Solar System.

It is true that this nebula subtends an angle of 2 1/3 degrees, but it is probable that many of the spirals are at a much greater distance, and are comparable in size. If the theory be found inadequate in some instances it becomes doubtful for all.

Whatever may have been the particular line of development represented by our own system, however, one thing is certain, the Sun must run the course of all stars and finally become extinct.

Must we then contemplate, as the end of this vast process, a state of death in which millions of exhausted suns wheel through infinite space throughout eternity? Surely not! As certain as the law of evolution is the law of dissolution, and progress is the resultant of the struggle between these contending forces. The cause of the dissolution of a single dark body may be inherent in the mass itself, or it may come from catastrophe from without.

A few years ago Thomson suggested a theoretical model of an atom, which imitated with great exactness many of the known phenomena of matter, and determined mathematically the conditions under which it could persist. This atom consisted of a positively charged sphere containing thousands of negatively charged corpuscles, whose stability depended upon a definite arrangement of their orbits; but as such an atom radiates energy a time must come when a redistribution of its components will occur, and an element requiring less energy be evolved. These changes might be exceedingly slow in some cases, but the system could not be eternal. How much less, then, that of the chemical combinations in a complex body like the Sun. Is the decay of matter a factor to be reckoned with? Putting this speculation aside, there remains the possibility of the rejuvenation of extinct suns by impact with other suns, or in the case of multiple systems, by the falling into the central body of its satellites, in consequence of tidal friction, or other causes of instability. The result would be, in all probability, the formation of a new nebula, and the beginning of a new life-history. Arhennius, in a recent work, leaves us with this as a final word: "Suns from Nebulæ; Nebulæ from Suns," but such a conclusion can never be satisfactory as a final statement. Evolution means progress, and though the tide may advance and recede it will, we believe, make a steady gain. According to Spencer, if you will pardon

me for again quoting that author (and it should not be forgotten that Spencer believed that he had discovered the law of universal progress in nature, organic or inorganic, and that cosmic evolution was only one of its many applications), evolution is continuous.

"Apparently," he says, "the universally co-existent forces of attraction and repulsion, which, as we have seen, necessitate rhythm in all minor changes throughout the universe, also necessitate rhythm in the totality of its changes—produce now an immeasurble period during which the attractive forces predominating, cause universal concentration, and then an immeasurable period during which the repulsive forces predominating, cause universal diffusion—Alternate eras of Evolution and Dissolution. And thus there is suggested a conception of the past during which there have been successive Evolutions analogous to that which is now going on; and a future during which successive Evolutions may go on—ever the same in principle but never the same in concrete result."

There is a line of investigation which so far has been but slightly touched upon—that of the influence of environment, or distribution in space, upon stellar character. Kapteyn has suggested a method of attack upon this problem based upon the selection for examination of limited areas of the sky, distributed in such a way as to give the greatest probability that the results obtained in such areas will apply to the whole heavens. These investigations will include the magnitudes, distances, and motions of stars in the areas named, and Hale announces that the photography of stellar spectra by the 60-inch reflector will be confined to Kapteyn's areas.

Messrs. W. Gibson and Karl Pearson are at present engaged in the valuable work of correlating stellar characters from the best available data, and have given some of their preliminary results in the *Monthly Notices* for March, 1908. The scope of their work includes magnitude, color, spectral type, proper motion, parallax, and position, as they believe that in any attempt to regard the stellar universe as a whole the relationship between

these characters must be of fundamental importance, and that their distribution is not a matter of chance but indicates a "differentiated organization."

Mr. W. S. Franks has also made some investigations into the relationship between star colors and spectra, finding a very high relationship between these characters, which is double that between magnitude and color.

A summary of these researches seems to show that while the color of a star may depend to some extent upon its magnitude, it is far more closely related to the spectral class, while the relation between parallax and spectrum is not much more than half that between magnitude and spectrum; that is, the chemical constitution of a star is of much more importance than distance in determining magnitude. As it was possible that a classification of spectra based chiefly upon temperature might yield a higher relationship between magnitude and color, Gibson and Pearson made a comparison between Lockyer's classification and the Harvard photometric magnitudes, with the result that their expectation was to some extent realized, the average magnitudes being greater on the side of descending temperature, although the order of magnitude did not agree closely with the classification order, and the result merely determined that the two characters were related.

In regard to the correlation of spectral class with proper motion, while the relationship is much less than between class and color, and class and magnitude, there is still a definite association which is independent of that between class and parallax.

The conclusions are that while the association between parallax, proper motion and magnitude is much less than might be anticipated upon the hypothesis of a uniform distribution of the stars, with a system of random velocities, yet that between color and spectral class, with magnitude, parallax and proper motion, suggests that chemical constitution and brilliancy, are in some manner related to a star's position and velocity in space.

Astronomical research is ceasing to be merely the work of individuals, or even of single observatories, and is becoming the charge of a vast organized army of skilled specialists; the weakness of one observatory being supplemented by the strength of another.

We look forward with expectation to the future, and especially, in the domain of astrophysics, is attention turned to the Solar Observatory at Mount Wilson where, under the brilliant leadership of Dr. Geo. E. Hale, new difficulties but suggest new methods of overcoming them, and each day almost is adding something to our knowledge of the great central luminary of our system.

The foregoing brief outline of some of the methods of attack upon the problem of cosmic evolution can suggest but faintly the great difficulties to be surmounted, or the vast field opened to speculation; the literature of the subject is, however, open to all, and a rich award awaits the student.

COMET 1908*c*, (MOREHOUSE)

By R. M. Motherwell.

THIS comet was visible for over three months, but dense smoke and unusually cloudy weather prevented any attempt at obtaining an extensive series of photographs. Single exposures were made on seven different nights, with the Brashear Doublet attached to the equatorial telescope. A filar micrometer was used in guiding and was very satisfactory in preventing drifting, but, owing to the smallness of its field, did not permit of the head of the comet being shifted appreciably from the centre of the camera field. Had it been possible to so shift the head, more of the tail would have been included in the photograph.

The following table gives the date and duration of each exposure:

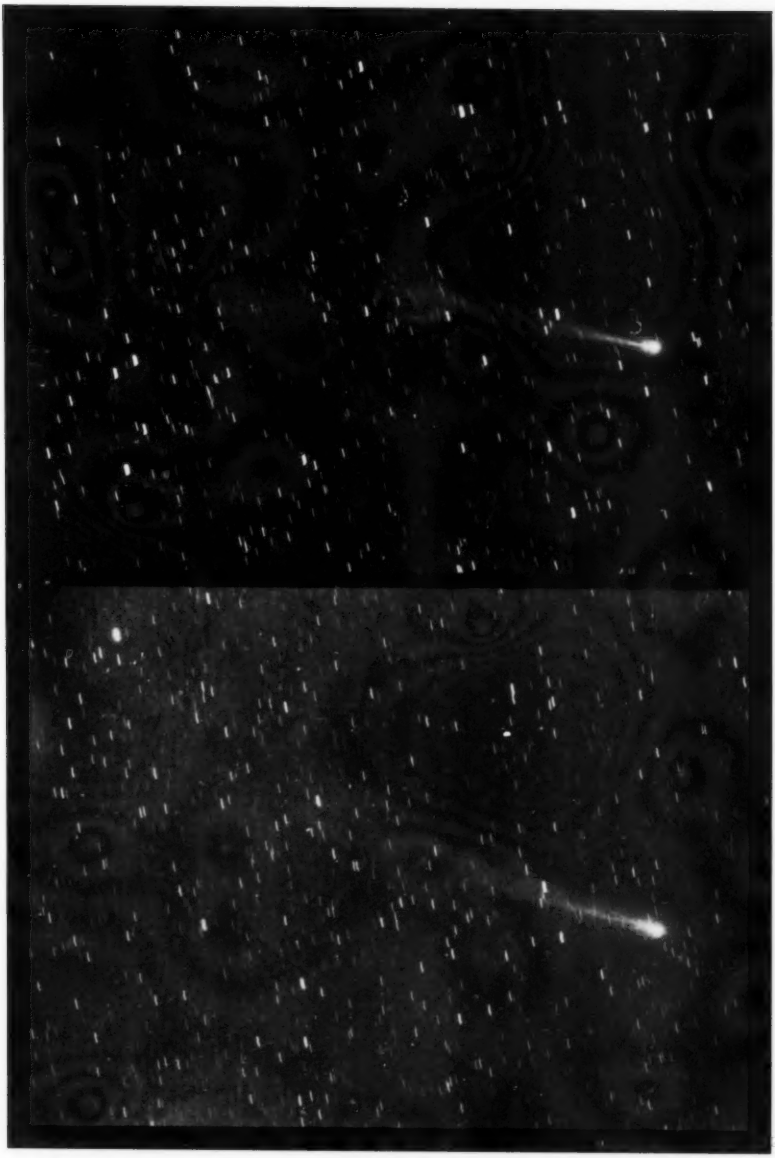
Plate	Eastern Standard Time	Beginning of Exposure	Duration	Remarks
	1908	h m	h m	
1	October 16	6 45	1 0	Very smoky
2	" 19	6 10	1 5	" "
3	" 31	7 25	0 55	Clear
4	November 1	7 15	0 55	Clear but unsteady
5	" 13	6 15	1 0	Very clear
6	" 26	5 30	1 25	Clear, high wind

An exposure of one hour was made on October 20 but the smoke was too dense. In the course of the exposure the head of the comet passed over an eighth magnitude star without perceptibly dimming it.

Plate I., *a*: The dense smoke accounts for the faintness of this photograph but still it is the most interesting one of the set, on account of the knots in the tail about one and a half degrees from the head. This portion seems to have separated from the head and drifted off while new matter has been given out. There has

PLATE I.

a



b

COMET MOREHOUSE, OCT. 16 (UPPER), OCT. 19 (LOWER).

Journal of the Royal Astronomical Society of Canada, 1909.

PLATE II.

a

b

COMET MOREHOUSE, OCT. 31 (UPPER), NOV. 1 (LOWER).

Journal of the Royal Astronomical Society of Canada, 1939.

also probably been a motion southward on the part of this detached mass, greater than that of the comet as the new matter in the tail connects with the north side of the knots while the southern part is altogether clear of the tail. The curved form of the central and southern portions of the detached mass is also worthy of notice. The new matter is connected to the head by a narrow neck and on either side, rays extend back about 0·5 degrees.

Plate I., *b*: This photograph is even more faint than fig. *a*, but the head shows considerable detail. The new portion of the tail spoken of in fig. *a* has apparently been forced back by the rays on either side, they being joined together now just back of the head. Although three days have elapsed between these exposures we can readily see that, during this interval, the comet has been very active internally.

Plate II., *a* and *b*, indicates a continuation of this activity. Fig. *a* shows several distinct knots in the tail about one to one and a half degrees from the head. Beyond these the tail gradually widens out, being uniform on the north side but broken on the south side. Fig. *b*, one day later, shows the same knots farther away from the head and more diffused. They seem to have been separated from the nucleus, the bright portion next to the head in fig. *a* broadening out here into a fan-shaped tail. Beyond the knots the tail has widened slightly.

Plate III., *a*, shows a very bright tail extending out about two degrees with short rays on both sides of the head. As in *a*, plate II., the north side of the tail is uniform while the south side shows offshoots. The comet was apparently in a very active state at this time, but thirteen days elapsed before I had an opportunity for another exposure, and *b*, plate III., shows a much fainter and divided tail. Evidently the activity has become much less, the faintness of the tail being partly due to its division into two parts, but more particularly to a change in the conditions governing the state of the comet's head. Are these changes in appearance due to some internal state or are they due to changes in the surrounding medium?

While this set of photographs can lay no claim to completeness it demonstrates clearly the necessity for frequent exposures at as close intervals as possible, if we wish to know with any degree of accuracy the changes actually taking place. It also shows that these exposures should not be too long, otherwise one plate might be a combination of several phases.

In conclusion I wish to express my indebtedness to Dr. King for the encouragement he has given me in this work.

DOMINION ASTRONOMICAL OBSERVATORY,
Ottawa, January 19, 1909.

PLATE III.

a

b

COMET MOREHOUSE, NOV. 13 (UPPER), NOV. 26 (LOWER).

Journal of the Royal Astronomical Society of Canada, 1909.

SIR WILLIAM HERSCHEL AND HIS ASTRONOMICAL WORK

By J. T. W. Claridge

AUGUST 23rd, 1907, was the eighty-fifth anniversary of the death of Frederick William Herschel (1738-1822), musician, speculum maker, and at the same time one of the greatest astronomers that England or the world itself has ever had. Comparatively speaking, little is known of him or his family. It is a Jewish name, and may be met with in Poland and Germany to-day. His father Isaac had ten children, of whom Frederick William was the fourth, and it was his great delight to see his sons devote themselves to the study of music. They attended the garrison school in Hanover until they reached the age of fourteen years. Here they were taught the three R's, to which was added a knowledge of French and English. The celebrated Caroline, born in 1750, tells us in her *Memoirs* how her father Isaac brought up the lads. She says: "My brothers were often introduced as solo performers and assistants in the orchestra of the Court, and I remember that I was frequently prevented from going to sleep by the lively criticism on music on coming from a concert, or by conversations on philosophical subjects, which lasted frequently till morning, in which my father was a lively partaker and assistant of my brother William. Often I would keep myself awake that I might listen to their animating remarks, for it made me so happy to see them so happy. But generally their conversation would branch out on philosophical subjects, when my brother and my father argued with such warmth that my mother's interference became necessary, when the names of Leibnitz, Newton and Euler sounded rather too loud for the repose of her little ones, who had to be at school by seven in the morning."

The brothers Jacob and William, with their father, were members of the Hanoverian Guard band, and in 1755 they were ordered to England, where they stayed twelve months. During this period William played the oboe, and out of his miserable pittances, he took back home with him, as a memento, a copy of Locke, *On the Human Understanding*. In 1756, the Seven Years War broke out, and William, finding that military life and hardships were not congenial to his taste, decided to quit the army by the simple, though risky, process of desertion. (It is pleasant at this point to record, that in after years when Herschel paid his first visit to George the Third, after the discovery of the "Georgium Sidus" (Uranus), the official document of pardon was handed to him by the King himself). After two or three years of hard struggle, he was appointed organist at the parish church of Halifax, having been previously Musical Instructor to the Durham Militia. In 1764 he returned to Hanover for a brief visit. We can, perhaps, imagine to some extent, his aged father joyously welcoming and congratulating him on his success, but what would the old man have thought could he have guessed the mighty achievements of his son's future career? Two years later, in 1766, William was promoted to the post of organist in the Octagon Chapel at Bath. Here, his brother Jacob assisted him. Sunday after Sunday, William's able organ performances attracted large and fashionable congregations, and these, together with his prepossessing and winsome manners, secured for him a host of friends and a goodly number of pupils for musical instruction. It is said that he gave frequently at this time, as many as 35 and 38 lessons every week. As a result, he became very well off. In perfecting his musical talents, his inborn love for knowledge, led him to study mathematics, Italian and Greek. The first works that attracted his attention, and which he eagerly studied during the intervals between his musical lessons, and every night, were Dr. Smith's *Harmonics*, and *Optics*, and Lalande's *Astronomy*. Gradually, this latter subject became so absorbing, that every spare moment was given to it. It was at this period, 1767, that his father died, after suffering two years of paralysis.

Caroline having lost her best friend, now transferred her affections to her brother William, and on his invitation joined him at 7, New King St., Bath. She was then 22 years old. Here, be it said, that a more devoted, a more loyal, a more loving sister never existed. The readiness and willingness to help and encourage her brother in every conceivable way, amounted to nothing short of reverence and adoration. As a result of studying Ferguson's *Astronomy*, Herschel borrowed from a friend in Bath, a small telescope, a two-and-a-half foot Gregorian, not only for the study of the heavens, but particularly for making experiments on instrumental construction. He speedily found that to see all he wanted to see necessitated a larger instrument, and so he determined to make one for himself.

It was in 1774, when he was 36 years of age, that he completed his great Gregorian telescope, and began his study of the heavens. He sent a copy of his first observation of Orion's nebula to the Royal Society, on March 4th, 1774.

Every night his telescopes were brought out sometimes in the garden, and sometimes in the street before his front door. Such was his burning enthusiasm that Caroline complained that almost every room in the house was turned into a workshop. The handsomely furnished drawing-room was used by his cabinet maker for making tubes and stands of every description. His brother, Alexander, now one of the party, used a bed-room for turning patterns, grinding glasses, turning eye-pieces and so on. William himself, occasionally forgot in his haste to get to work, to take off his beautiful lace ruffles, which he wore at a concert, and which, at times, were torn or covered with pitch. In fact, the house offered more room for workshops than a dwelling place, and in addition he had a place made on the roof for observing. A great deal of Caroline's time was occupied in copying music and practising, besides waiting on her brother when he was polishing the mirrors, for she was constantly obliged to feed him by putting the food by bits into his mouth. At one time, in order to finish a seven-foot mirror, he did not take his hands from it for sixteen hours. This shows the indomitable persever-

ance of the man. At night time, Caroline would sit beside him at her desk, ready to take down every note he made in his scrutiny of the heavens. Oftentimes his observations lasted throughout the whole of a long winter's night, and there are but very few women who could have stood such a severe task as that, for Caroline says, that sometimes she had to stop because the ink was frozen on her pen. Such, however, was her devotion, that she never complained. After a brief rest, she resumed her labors of correcting and reducing the figures, and accurately arranging all the observations. It was in 1780 that Herschel communicated to the Royal Society two papers, the first being "Astronomical Observations on the Star in Collo Ceti," *i.e.*, the variable star *Mira Ceti*; the other, "Astronomical Observations on the Rotation of the Planets round their Axes, made with a View to determine whether the Earth's diurnal motion is perfectly Equable." In the same volume of the Society's *Philosophical Transactions*, in which the two papers appear, is an "Account of a Comet." This paper was read April 26th, 1781. The so-called comet turned out to be the major planet Uranus, or, as Herschel named it, "Georgium Sidus." He discovered it on that ever memorable night of Tuesday, March 13th, 1781. It would appear that he had proposed to himself the task of systematically studying all the stars above a certain magnitude. Hundreds and thousands passed his telescopic field of view, and were eagerly scanned. On the night aforsaid he was examining the stars in the constellation of *Gemini*, when one struck him as appearing larger than the rest. Of course, a star properly so called, appears simply as a minute point of light, which no increased magnifying power will ever show as a true disc. This is owing to their enormous distances from us. When he compared it with the other stars in the vicinity, he found it larger than any of them, and immediately suspected it to be a comet. On applying a higher magnifying power, and observing, that after a few nights of close watch, it had shifted its place among the stars, he at once announced that it was a planet, and not a comet. Throughout the whole scientific world, astonishment of a profound nature

was evinced, when the discovery was made that the five planets, known from remote antiquity, must now admit the presence of a sixth. Repeated study found that it was by no means an insignificant object, that it swept round the Sun in an orbit far outside Saturn, till then the remotest planet of the solar system, and that its period of revolution was 84 years. It may be surmised of Herschel, that his magnificent astronomical achievements were rather the natural consequence of new facts acquired to human vision through the patient and steady development of a true mechanical agency, than indications of any great intuitive mental ability; intellectually speaking, Newton and Laplace soared above him; he represented untiring labor, which on this occasion gave its reward. Nature, when making a series of revelations as great as she ever made before, chose as her channel here, neither great brains nor great learning, but simply a self-educated musician, who had a strenuous desire to improve himself, and his burnished reflector gave him an experience then unprecedented in the recorded history of mankind, the sight of a new and unknown planet. At this time he was only plain, "Mr. William Herschel, of Bath." It was not until 1786, that the degree of LL.D. was conferred upon him by Oxford University. The fame of the Hanoverian musician soon reached the ears of King George III., who, in the spring of 1782, commanded him to Windsor, and to bring with him the famous telescope for the King to see the new planet and hear everything about it. The instrument was a seven-foot Newtonian of 6¼ inches aperture, and for distinctness of vision, Herschel claimed for it that "it was equal to any that was ever made." The result of the visit was what Herschel most earnestly desired—the position of being able to devote the remainder of his life to the advancement and development of his favorite science. The King, after pardoning his desertion from the army, conferred on him the title of "Royal Astronomer," gave him a residence near Windsor, and provided him with an annuity of £200 yearly. Other funds also were allowed as might be required for the building of larger instruments, and for the prosecution of that scheme he had laid out

for himself, viz., the study of the construction of the heavens.

On August 1st, 1782, he took up his official abode at Datchett, near Windsor. His last musical duty was performed on Whit-Sunday 1782, in St. Margaret's Chapel, Bath, when the anthem for the day was one of his own composition. Henceforth, he lived in his own observatory, and from his forty-fourth year onwards, he only left it for short periods to go to Greenwich, or to London to submit his various papers to the Royal Society, to which he was admitted a Fellow, May 30th, 1782, having previously received the Copley Gold Medal for his discovery of Uranus. The house at Datchet was in a very wretched and miserable condition, almost uninhabitable, so he subsequently removed his whole establishment to Slough. Here he worked with his now completed twenty-foot reflector, Caroline helping him, and at odd times sweeping for comets. In the course of her life, she discovered no less than eight, and five of these were first seen by her. She was appointed Assistant Astronomer, in 1787, to her brother at a salary of £50 a year, and in her *Memoir* she says: "In October I received £12-10-0, being the first quarterly payment of my salary, and the first money I ever spent in all my life-time,—thought myself to be at liberty to spend to my own liking."

He married on May 8th, 1788, Mary, the only child of Mr. James Baldwin, a merchant of the city of London, and widow of Mr. John Pitt. She was a lady of singular amiability and gentleness of character. They had but one child, John Frederick William, born March 7th, 1792. From henceforth Caroline lived in lodgings, coming every day for her work, and in all respects continuing the same labors as before. Some short time before, in 1786, Herschel paid a visit to Hanover to his aged mother, whom he never saw again. The tube of the great forty-foot telescope, on which he had long been engaged, was now completed, and it was the fashion with visitors to use it "as a promenade," before the mirror was fixed. A Dr. and Miss Burney called to see it one day and "to take a walk" through it. George III. and the Archbishop of Canterbury followed the

general example, but the prelate finding it difficult to proceed, the King turned to give him his hand, saying, "Come, my Lord Bishop, I will show you the way to Heaven!" This great instrument took rank, before and after its completion, as the chief scientific wonder of the age. The mirror was nearly 50 inches in diameter, and weighed 2,118 lbs. It was slung in a ring, and the sheet-iron tube in which it rested was 39½ feet long, and 4 feet 10 inches wide. Ladders 50 feet long gave access to a movable stage, from which the observer communicated through speaking tubes with his assistants. The whole erection stood on a revolving platform; for the modern equatorial form of mount, by which the diurnal course of the heavens is automatically followed, was not then practically available, and the necessary movements were consequently made by hand. Herschel estimated that with a magnifying power of 1000, this grand instrument could, in the English climate, be effectively used during no more than 100 hours every year. A review with it of the whole heavens would hence have occupied eight centuries.

It was only a short time after this, that he discovered two satellites of Uranus, a by no means easy achievement in those days of the absence of the highly sensitized photographic plate now so universally employed. He pictured the heavens as "a luxuriant garden, containing the greatest variety of productions in different flourishing beds." The nets spread in his "sweeps" captured, besides double stars, plenty of the filmy objects called "nebulæ." The heavens seemed full of them. He presented a catalogue of 1000 to the Royal Society in 1786, a second list equally comprehensive in 1789, and a third of 500 in 1802. He thus describes them as consisting of aggregations of genuine stars, and it was almost inevitable that he should do so, but we know now from modern spectroscopic analysis, that they are masses, for the most part, of incandescent gases.

The time had now arrived when his health began to break up, and in the spring of 1808 he became seriously ill. He was now 70 years of age, and the only long series of observations

which he subsequently made after his restoration to health, were upon the comet of 1811. He now deemed it obligatory to make frequent excursions for change of air and scene. Caroline remained at home, arranging into order the numerous manuscripts, and copying the papers for the Royal Society. She was very much distressed, fearing that each time she saw her brother, that it would be the last. On February 11th, 1818, she writes: "I went to my brother and remained with him till the 23rd. We spent our time, though not in idleness, in sorrow and sadness." On a subsequent note from him, she wrote: "Every line now traced by the hand of my dear brother becomes a treasure to me." In 1816 he was created a Knight of the Royal Hanoverian Guelphic Order, and was eventually appointed the first President of the Royal Astronomical Society in 1821. The days of his earthly career were now drawing to a close. He spent most of his time now in putting his works in order. Caroline says, "the anxious care for his papers and workrooms never ended but with his life, and this was proved by his frequent whispered inquiries if they were locked, and the key safe, of which I took care to assure him that they were safe, and the key in Lady Herschel's hands." "For ten days and nights we [Lady Herschel and herself] remained in the most heart-rending situation till the 25th of August, when not one comfort was left to me but that of retiring to the chamber of death, there to ruminate without interruption on my isolated situation. Of this last solace I was robbed on the 7th of September, when the dear remains were consigned to the grave." He was 84 years of age. His remains lie in the little chapel at Upton, near Windsor, where a memorial tablet has been erected by his son Sir John Herschel. On this tablet are engraven the words, "*Cœlorum perrupit claustra*" (He broke through the barriers of the skies). Professor Holden describes him as "a practical astronomer without an equal, and in very truth his is one of the few names which belong to the whole world."

It is worthy of notice that Herschel contributed to the Royal Society no less than seventy-nine papers. These comprise, among

others, "Researches on the Relative Brightness of the Stars." For three years a patient investigation was made to elaborate a classification of the stars according to their comparative brightness. He did this in the prosecution of his great idea to work out "the construction of the heavens." This study extended over the whole of his scientific life. By this title he specially meant the method according to which the stars, clusters and nebulæ, are spread through the regions of space, the causes that have led to this distribution, and the laws of its government. His researches on the parallaxes of stars were for the purpose of gaining an unit of celestial measure by which the depths of space might be fathomed.

In his study of the Variable Star section, *Mira Ceti* was closely watched. Here he saw a star, shining by its own inherent brightness, waxing and waning like the Moon in its periodicity, which lasts 333 days. The question occurred to him, "Are all other stars constant in brightness?" After repeated observations he found some stars whose light was progressively diminishing, others which regularly increased, and at least one star (*55 Herculis*) which has entirely disappeared. Now the cause of these strange variations of brightness was supposed by Herschel to be the rotation of the star bodily on an axis, by which rotation different parts of its surface, of different brightness, were successively brought into view.

The double stars formed the subject of his earliest and latest papers. By 1802 he persuaded himself that there existed in the heavens real pairs of stars, "binaries" as he called them, which are physically connected with each other, both revolving round their common centre of gravity.

With regard to his planetary researches we learn that though he bestowed a considerable amount of attention upon them, no important memoirs were written. The planet Saturn, two of whose satellites he discovered in 1789, seems to have attracted him the most, for he never lost sight of it, from the time he first saw it in 1772, till the end of his life. Altogether he published

six accounts on the figure, the ring and the satellites of the planet.

In 1783, he published a remarkable paper "On the Proper Motion of the Solar System." The fact that certain of the stars had a proper motion had been well established by the astronomers of the eighteenth century, and that these proper motions of the stars were due partly to their own real motion, and also to the Sun's motion in space. Herschel was the first to investigate and determine the direction of this motion. The result at which he arrived was, that the Sun is now moving towards a point in the constellation of Hercules. This point is known as "the apex of the Sun's way." More recent investigations locate the point near Vega in Lyra.

In concluding this brief sketch of the life and labors of the great astronomer, it is well for us to remember that he was born with the faculties which fitted him for his gigantic efforts, and more than that he was possessed with that indefatigable basis of energy and principle which clung to him all through his scientific career. His musical abilities were afterwards developed in the deep and solemn harmony of the spheres. His mighty intellectual genius unravelled their mysterious movements and prepared the way for future generations to a more accurate grasp of their meaning. Long will his memory be cherished and admired in the annals of astronomical science.

BURTON-ON-TRENT,
England.

SOLAR ACTIVITY IN DECEMBER, 1908

By Luis G. León and Mrs. León

THE instruments we use for the study of the Sun are an equatorial, made in Paris by Mailhat, with 80 mm. aperture, and provided with photographic camera, and a telescope, from Bardou of Paris, with 75 mm. aperture. This last instrument has very clear lenses, and we find it very good for visual studies, but the equatorial gives better projections and we use it for determining the position of the spots.

On Tuesday, December 1, the Sun's disk presented only three small spots, one in the eastern region and two in the S.W. quadrant. These spots were insignificant, but in the N.E. region and just on the edge of the Sun there were brilliant faculæ which occupied at least 15 degrees of the limb. We thought that these faculæ were the forerunners of some large spot. Indeed they were. On Wednesday 2nd on directing our telescopes to the Sun we could see, between the E. and E.N.E. points of the edge, a long black line surrounded by vivid streaks of white light. Our first drawing shows the appearance of this spot. (See Plate IV.) On Friday 4th a little pore came following the large spot. We measured the spot and found it 1′, which corresponds to 43,228 kilometers, and if we remember that the diameter of the earth is equal to 12,742 kilometers we may think that our earth with all its unhappy inhabitants could easily go inside that spot. The penumbra was especially deserving of note in this spot. It was very large and of a dark gray color. On Tuesday 8th the spot measured 1′ 15″. A photograph which we took of that spot allowed us to confirm the measurement. Figure 2 shows the aspect of the spot on this day. On Sunday 13th, when very near the western edge, the spot showed a curious appendix towards the east, almost up to the limit of the penumbra. On Monday 14th the spot had an appearance almost similar

to that it had on the 2nd, and on Tuesday 15th it disappeared.

On Tuesday 15th the Sun looked at first sight spotless. Only with great care was it possible to distinguish small pores.

Now comes something very important in the Sun's history of this month. On Wednesday 16th only three very small spots could be seen near the central meridian and near the centre of the Sun. On the next day a very conspicuous group was visible. Those three small spots of the preceding day had transformed in a very noted manner. We saw a large western spot followed by two small ones, and then by two larger ones. There were nine nuclei in all. Besides, two more small, but very black spots were seen further up, that is to say towards the east.

On Friday 18th the group was very beautiful (see figure 3). There were 13 nuclei, and the streaks of the penumbra and the faculæ showed that there were in that region of the Sun great photospheric currents, working with terrible energy. On Saturday 19th the sight was still more interesting. Both parts of the spot, the eastern and the western one, had had a cyclonic movement and showed a tendency to separate one from the other. Besides, the nuclei had broken in small portions and it was possible to count 28 of them (figure 4). On Sunday 20th we saw two large spots perfectly defined, with only a small spot between them. The aspect of the eastern one reminded one of a Japanese mask. At last, on Monday 21st the western spot was perfectly formed. It was what we could name a normal spot, with a dark elliptic *umbra* and a gray and also elliptic *penumbra*. The eastern spot was in process of disintegration.

Generally, as we very well know, solar spots appear on the eastern edge of the Sun and after 13½ days disappear, but this beautiful group formed right on the center of the Sun. It was indeed a sudden eruption, and three very little spots gave genesis to a very interesting group.

It is at present very difficult to ascertain a relation between solar spots and meteorological or geological phenomena, but we may say as a mere coincidence, that on Friday 18th, when this beautiful group was crossing the central meridian of the Sun,

PLATE IV.

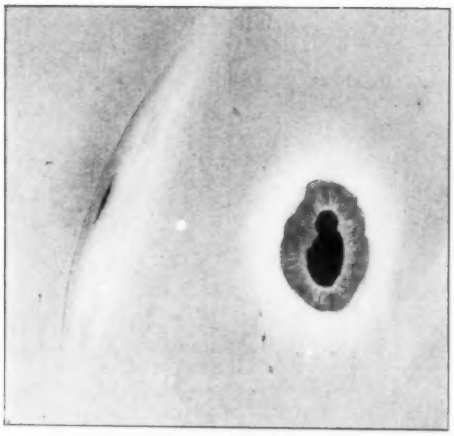


Fig. 1 Fig. 2

Fig. 3

Fig. 4

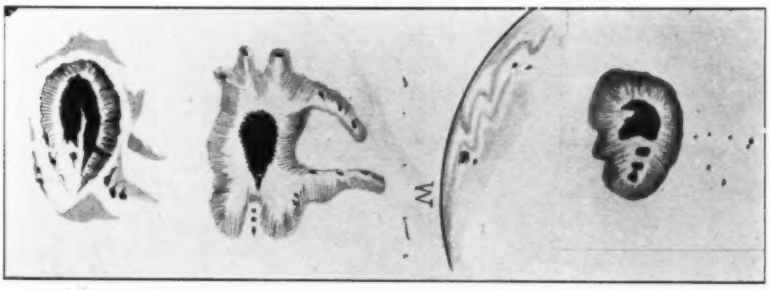


Fig. 5 Fig. 6 Fig. 7 Fig. 8

SUN-SPOTS, DECEMBER, 1908.

Journal of the Royal Astronomical Society of Canada, 1909.

the Mexican volcano of Colima had, at 3 o'clock in the afternoon, a great outburst which was witnessed by thousands of frightened inhabitants.

On December 22nd there were what we might call two outbursts of very small spots, one on the S.E. quadrant and another on the S.W. quadrant. Besides, the other groups had divided into many small spots and pores.

On December 23rd there were two groups of spots on the Sun, and brilliant faculæ over the western limb. On the 24th appeared a new group on the central meridian.

On December 27th appeared a new group of very soft spots on the S.E. quadrant, but at the same time the group which appeared the 24th on the central meridian suddenly disappeared. We expected to-day the reappearance of the great spot of December 2nd, which disappeared on December 14 but at the observation hour (8 A.M.) nothing had yet appeared.

On December 28th at 8 A.M. the large spot was visible in the eastern region of the Sun and from the distance which it was from the limb there is no doubt that it appeared on the afternoon of the previous day. The penumbra had two nuclei and it was surrounded by very brilliant faculæ. There was also a group very near the western limb and a group of very small spots on the N.E. quadrant. This day we received, late in the afternoon, the sad news of the earthquakes in Sicily and Calabria. Of course it is very difficult at present to establish exactly what kind of relation exists between solar spots and the earth's phenomena, but it is probable that some relation exists.

On December 29th the eastern limb of the Sun presented a very beautiful appearance. The large spot had a wide penumbra with four nuclei (fig. 5). A new and large spot made its appearance, and between the two large spots there were two penumbras with very small nuclei. Wide and shining faculæ surrounded all. The faculæ that existed on the western limb looked like water-currents, like waves of sea-water formed over the sand of a coast during the rising tide (fig. 6). There was a beautiful group of small spots on the meridian.

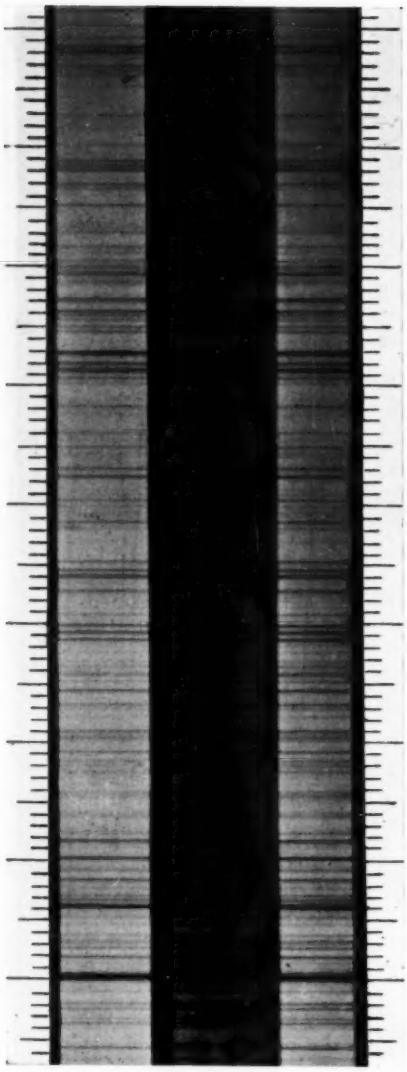
On Wednesday 30th the penumbra of the large spot had two prolongations something like two extended arms or tentacles directed towards the south (fig. 7), and the penumbra showed a breakage in the eastern part of it. It is indeed a very curious shape of penumbra, not very common. Large faculæ at the east and the west.

The old year appeared sad on the morning of Thursday, 31st of December, 1908. It was somewhat cloudy and foggy. But by using the best moments we made a drawing of the large spot. The penumbra had transformed itself greatly (fig. 8), as we could see by comparing its shape with that of the previous day.

The month of December, 1908, was one of great solar activity, notwithstanding that we are in a minimum period.

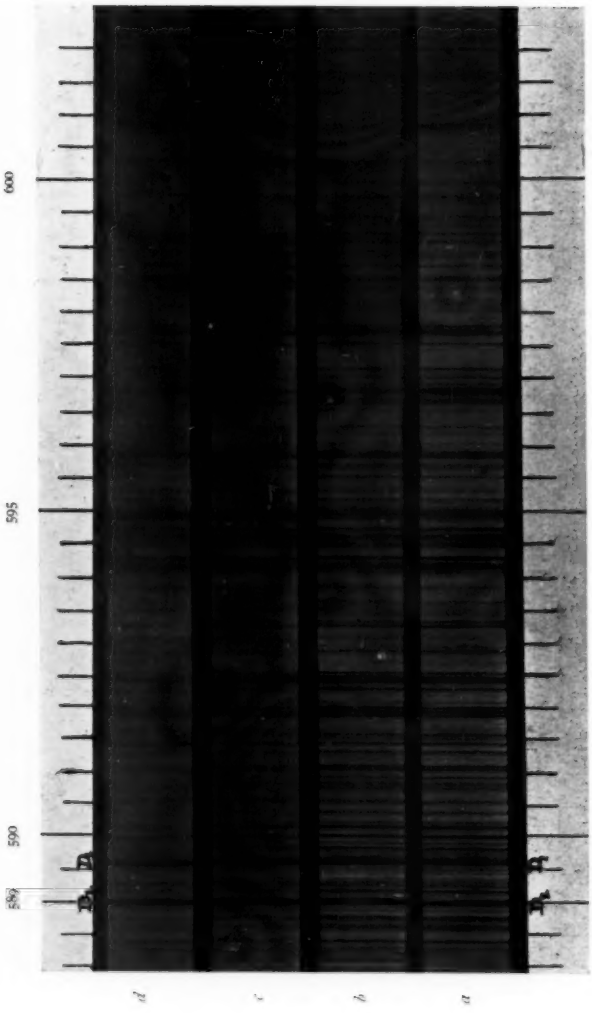
Mexico, December 31, 1908.

PLATE V.



The outer strips are the spectrum of the eastern or approaching limb of the Sun; the inner, that of the western or receding limb.

PLATE VI.



Spectrum of the Sun; *a* and *b* at low altitudes, *c* and *d* at high altitudes. Showing lines due to vapor in the atmosphere.

SPECTRA OF WATER-VAPOR IN THE EARTH'S ATMOSPHERE

By L. Gilchrist

THE following work was undertaken at the Dominion Observatory at Ottawa in the hope that a photographic record of the water-vapor lines in the earth's atmosphere might be obtained, from which the changes in the intensity of the lines corresponding, the changes in the atmospheric conditions could be estimated. There is considerable variation in temperature and humidity in this district during the year, and it seemed to be a suitable place for such experiments.

Work on the intensity of the water-vapor lines has been carried on at other stations, *e.g.*, by Prof. W. W. Campbell,* by A. Cornu,† by J. E. Keeler‡ and by others, in which estimates of the intensity were made visually upon the lines directly and from photographic records. Mr. L. E. Jewell§ has also made visual observations at Baltimore extending over a lengthy period, and considered the method more satisfactory than making photographic record. The many advantages of the latter, however, make it appear desirable to obtain such records if possible. The experiments of this Observatory were commenced in July, and the results obtained warrants the continuation of the work at intervals, until at least records are obtained which will show the intensity of the lines during the seasons or during abnormal conditions of the atmosphere, and Dr. R. E. De Lury has kindly consented to continue the work during my absence.

From a consideration of the water-vapor lines in Rowland's tables it was decided to use the portion of the spectrum adjacent to the *D* lines, as the water lines are numerous and very pronounced in that region, among which are the important ones mentioned by Hale and Wadsworth‖ 5886·193, 5887·445; 5901·

* *Astrophysical Journal*, vol. 2, p. 28, 1895. † *Idem*, vol. 13, p. 142, 1901.
‡ *Idem*, vol. 5, p. 328, 1897. § *Idem*, vol. 1, p. 311–317; vol. 4, p. 324, 1896.
‖ *Idem*, vol. 4, p. 65, 1896.

682; 5910·860. Angström units. This is the portion of the spectrum shown in Plates V. and VI.

Plate V. shows the method used to identify the water-vapor lines. A comparison of the inner spectrum with the two outer adjacent spectra will show the atmospheric lines unshifted, while the solar lines in the inner spectrum are shifted to the right. This is seen to better advantage if the spectra are examined with an eye-piece or magnifying glass. The following table of the most prominent lines may assist in the identification of the lines.

Solar	Intensity	Water-vapor lines	Intensity
5890·186	30	5887·445	5
5893·097	4	5887·880	3
5896·154	20	5889·920	2
5899·518	·6	5889·855	3
5902·694	·7	5890·100	2
		5891·398	1
5905·895	4	5891·878	4
5907·060	1·5	5892·608	3
5910·197	2	5893·725	1
5914·383	6	5898·378	4
5916·475	3	5900·260	4
5918·773	1·5	5901·682	6
5922·334	1·6		
5929·898	2·8	5909·213	3
5930·406	6	5910·987	2
5934·883	4·8	5913·212	3
5948·765	5·5	5914·430	6
5949·566	2	5918·635	4
5952·943	3·5	5919·276	5
5956·923	3	5919·860	7
		5922·735	2
		5924·040	2
		5924·490	4
		5925·220	2
		5932·306	5
		5941·290	5
		5941·845	2
		5942·789	3
		5946·223	3
		5949·390	2
		5966·055	2
		5968·058	2
		5968·495	2

The photograph is that of the spectrum of the second order, obtained by means of a cœlostat giving an image of the Sun 9″ in diameter and a Michelson grating 4¾″ x 4¼″ containing 15,000 lines to the inch and mounted as a Littrow spectroscope with a lens of 23 focal length. The inner spectrum and the two adjacent spectra were produced by light from opposite limbs of the Sun, approximately on the Sun's equator, and the shift is, of course, a Doppler effect.

The instrument which was used for the purpose of making the records of the intensity of the water-vapor lines is a Rowland concave grating of width 4″, containing 15,000 lines to the inch and focal length of 10 feet, equipped with an adjustable camera so that several exposures may be made on one plate. Plate VI. is an example of the photographs of the second-order spectrum obtained with this instrument.

Preliminary work consisted in adjusting the instrument, and obtaining suitable plates, method of exposure, screen and developer, as well as obtaining records for different altitudes of the Sun. Plate VI. shows that a very considerable difference exists between the intensity of the lines.

The work of L. E. Jewell showed that at Baltimore there is about five times as much water-vapor in the atmosphere in June as in January, and the vapor lines are on the average about fifteen times as intense at the lowest altitudes of the Sun as at the highest, *i.e.*, the maximum change in intensity during the year is about one-third of that from sunrise to noon. An inspection of Plate VI. shows a marked difference in the intensity of the lines in morning or evening and at noon (spectra (*a*) and (*b*) were obtained at low altitudes, and (*c*) and (*d*) at high altitudes of the Sun) and leads to the conclusion that one-third of this difference or even much smaller fractions can be approximately estimated, and through practice in estimating intensities visually or by comparison with Standard lines close approximations may be obtained, and by keeping the record over a considerable period abnormal conditions of the atmosphere may possibly be detected.

Some of the chief difficulties in keeping a satisfactory photographic record and the proposed methods of dealing therewith are as follows :—

(*a*) It is necessary to have as far as possible uniformity in plates, exposures, solutions, temperature and developing and fixing conditions generally. The plates used are Cramer's Isochromatic (Medium), 3⅜″ by 2½″, cut from large plates, a supply of which was set apart for the purpose and kept together in a dry and cool place. The plates are fairly fast in the *D* region but are much slower for the orange and red. The rapid weakening of the image towards the red end, however, assists the observer greatly in determining the extent of similarity in the exposures. Five exposures may be taken on a plate and the plates are kept until a considerable number accumulate. They are then developed and fixed together, a few being reserved to be developed with the succeeding lot to serve as a check upon possible changes in the plates. As a guide in exposure the Wynne exposure meter is used. It is placed in the path of the beam as it emerges from the slit and in such position that its shadow just falls below the grating. A much better position would be in the direct image from the grating or in one of the adjacent spectra, but paper for the meter of sufficient activity was not obtainable.

(*b*) Another difficulty is the uncertainty of the weather conditions, the presence of clouds for some time making discontinuities in the records, and at times the haze and smoke is such that long exposures are required during which, in the morning and evening, the intensity of the vapor lines changes considerably, diminishing greatly the value of the record. On a fairly clear day the exposures required vary from about 15 min. when the Sun is near the horizon, and 4 min. when it is at an angle of about 15° to 1½ min. at noon. A reference to Plate VI. will show that except for the lowest altitude these lengths of exposure do not prevent a fairly good estimate of the intensity corresponding to a particular altitude. It was decided to make an exposure every hour when the atmospheric conditions permitted it, in order that from such a large number those which, from error of exposure or other

defect, were unreliable might be discarded without seriously affecting the record.

From the plates which have already been obtained differences of intensity may be detected, and it is hoped that the changes in intensity with greater changes in weather conditions will be readily shown by the photographs.

In conclusion I wish to express my sincere gratitude to Dr. W. F. King, Chief Astronomer at Ottawa, for the opportunity of carrying out this work, and also to Mr. J. S. Plaskett, B.A., and Dr. R. E. De Lury for many helpful suggestions in connection with the work.

A REMARKABLE CLASS OF SPECTROSCOPIC BINARIES

By J. Miller Barr

THE type of binaries here referred to is that of which *β Arietis*, *ι Orionis*, *θ Aquilæ*, and *B. D.*—1° 1004 (Orion) are the chief known examples. In each case, the oscillation-curve is very unsymmetrical; the *descending* branch of the curve being much steeper than the *ascending* branch. These curves exemplify, therefore, the prevailing law or relation,

$$D < I$$

to which the writer has recently called attention.* I have tried to account for this law on the basis of two probable assumptions, viz.:

(1) That the spectrum-giving star rotates rapidly in the same general direction as it revolves in its orbit.

(2) That the star's surface is unequally bright in different *longitudes*;† this condition being due to the tidal action of the companion-body.

It was found, however, that extremely unsymmetrical curves —such as those under notice—could not be adequately explained in this way.

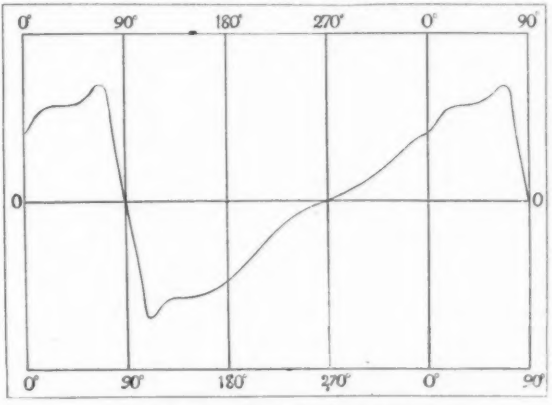
The object of the present note is to suggest another explanation, which accounts for the chief features, at least, of the curves in question. According to this theory, the stars under notice are *variables of the Algol type*. If we assume, as before,

* *Jour. R. A. S. C.*, March April, 1908, p. 70; *Popular Astronomy*, April, 1908, p. 259. The law in question holds good, in particular, for those stars whose oscillation-curves are distinctly unsymmetrical. In many cases, however, the asymmetry is slight; and for such stars, the effects of *elliptic* motion must often be relatively large, and, in some cases, of paramount importance.

† The term "longitude" here refers to *position on the star's surface*, and not to the star's *orbital* longitude.

that the revolving star* turns rapidly on its axis, it is easily seen that spectral changes must occur while the partial eclipses of its light are in progress. Thus, *before* central minimum, the spectrum lines (as regards their *mean* positions) would be displaced towards the *red*; whilst *after* minimum they would be displaced towards the *violet*. The curve representing this *eclipse-rotation* effect (as we may call it) must now be combined with two other curves, viz., (*a*) the sine-curve, representing motion in a circular orbit, (*b*) a curve depicting the "axial motion effect," due to tidal action, as already defined.

The resulting oscillation-curve will be of the general type shown in the accompanying diagram.† This curve, it will be



A TYPE OF OSCILLATION CURVE

seen, shows distinct inequalities in the ascending branch. It becomes, therefore, a question of great interest, whether similar features occur in the *observed* oscillation-curves. Now, in the case of θ *Aquilæ*, I find that the observations (as plotted at the Dominion Observatory‡) do, in fact, afford evidence of irregulari-

* In each case, the orbit is regarded as circular.

† Considerable diversity in detail might be looked for among curves of this class—according to the varying conditions involved.

‡ *Journal R. A. S. C.*, November-December, 1907, p. 357.

ties which correspond roughly in form and position to those shown in our diagram. Some traces of similar inequalities appear (though indistinctly) in the oscillation-curves of *ι Orionis* and other stars—as drawn carefully among the points represented.

On the whole, it may be said that our present hypothesis affords a not unpromising explanation of the observed facts. It is applicable, moreover, in cases where the oscillation-curves are much less unsymmetrical than those of the stars under notice; though, in such cases, the *tidal-rotation effect*, as originally suggested, may afford a more probable solution.

It is not necessary to suppose that the eclipsing body (as here postulated) cuts off a large part of the star's light. A variation of 0·3 to 0·5 magnitude—such as might easily have escaped detection in an Algol star—would probably suffice to explain the observed oscillation-curves. The epoch of minimum brightness would evidently correspond to a fairly definite point in each curve—viz., that where the *decrease of "radial velocity" is most rapid*. Thus the theory may be subjected to a decisive test, by means of accurate photometric observations. Meanwhile, the method of Argelander may be utilized for the same purpose. With this object in view, the writer hopes to secure effective observations of each of the four stars mentioned above. The stars will be observed at and near the computed times of minimum brightness—according to our present hypothesis*—and again at *maximum*. A comparison of such observations (made by an improved method whose reliability is shown by recent tests) should lead to a definite conclusion on the subject.

ST. CATHARINES, ONT.,
December 19, 1908.

* The *duration* of such minima, would, in general, be relatively short, as compared with the minima resulting from axial rotation. The times of minima would, however, be the same on the two hypotheses—if we assume that the longer axis of the tidal wave is directed towards the tide-raising body, and that *high-tide* corresponds to minimum surface-brightness.

ERRATA in paper on "The Orbits and 'Velocity-Curves' of Spectroscopic Binaries" (*Jour. R. A. S. C.*, Vol. II., p. 70, 1908) :—

P. 70, diagram :—The writer's original drawing has unfortunately suffered in the reproduction : one of the radial lines has been omitted, and in several cases the positions of the lines are not correctly shown.

P. 71, list of binaries, for "*α Carinæ*" read "a *Carinæ*."

P. 74. The first footnote on this page should be cancelled.

P. 78 ("Supplementary Note") line 8, for "was regarded as" read "is clearly."

MEETINGS OF THE SOCIETY

AT TORONTO

December 15, 1908.—The following were elected members of the Society :

Mrs. M. M. Manley, Meaford.

F. R. Tubb, 599 Wellington St., W., Toronto.

Major J. A. Sladen, 722 Flanders St., Portland, Ore.

Professor L. B. Stewart gave a paper on "The Determination of Latitude."

After giving the different meanings attached to the word "latitude," an account was given of the various methods of determining the astronomical latitude, depending upon the measurement of altitudes of heavenly bodies, describing the methods of observing with the theodolite and sextant. Talcott's method with the zenith telescope was also described, showing its superiority over methods depending on absolute altitudes. A description was given of the method by "double altitudes," showing also its application to the graphical construction of the place of a ship at sea by circles of position on a terrestrial globe.

The address was followed closely, and at the close an interesting discussion took place, in which Mr. Miller and Mr. Musson took part.

January 12, 1909.—The Society's Annual Meeting and Conversazione was held in Victoria College.

The Secretary reported the result of the balloting for officers for 1909, as follows :—

Honorary President.—W. F. King, C.M.G., LL.D., Ottawa.

President.—W. Balfour Musson, Toronto.

First Vice-President.—Professor A. T. De Lury, Toronto.

Second Vice-President.—Professor L. B. Stewart, Toronto.

Secretary.—J. R. Collins, Toronto.

Recorder.—Miss Elsie A. Dent, Toronto.

Treasurer.—J. Edward Maybee, Toronto.

Librarian.—A. Sinclair, Toronto.

Curator.—R. S. Duncan, Toronto.

Council.—Rev. I. J. Kavanagh, S.J., Montreal; A. F. Miller, Toronto; R. Stewart Muir, Toronto; J. S. Plaskett, B.A., Ottawa; Joseph Pope, A.M.G., Ottawa.

The presiding officer at each Centre is also a member of Council, as follows:—

G. Parry Jenkins, Hamilton.

Rev. Dr. Marsh, Peterborough.

Dr. Otto Klotz, Ottawa.

The President reported that at a meeting of the Council held on December 22 the names of several members of the Society had been proposed for election as Fellows. Fellowship is conferred in recognition of original scientific work of merit or in virtue of high scientific attainments or services. The Secretary read the list, as follows:—

William Frederick King, B.A., C.M.G., LL.D., Chief Astronomer for Canada, Ottawa. Has conducted for Canada important boundary surveys; also done much other scientific work for the Dominion Government. Author of an important paper on "Determination of Orbits of Spectroscopic Binaries."

Clement Henry McLeod, Ma.E., F.R.S.C., Mem. Can. Soc. C.E., Superintendent of McGill College Observatory, Montreal, Que. In charge of geodetic work at McGill University. Author of a treatise on Geodesy.

Otto J. Klotz, LL.D., F.R.A.S., Ottawa. Dr. Klotz has done important work in transcontinental longitude and pendulum observations, and has carried longitude determinations across the Pacific Ocean completing an astronomical girdle of the globe (see *Trans. R.A.S.C.* for 1905).

John Stanley Plaskett, B.A., Ottawa. Mr. Plaskett has made important investigations into the photography of natural colors. (*Trans. Can. Inst.*, vol. 7, p. 371, 1901-2; *Trans. R.A.S.C.*, 1905, p. 89). His researches in astrophysics at the Dominion

Astronomical Observatory have been numerous and important. (R.A.S.C. JOURNAL for 1907 and 1908; *Astrophysical Journal* for 1907 and 1908).

Robert Meldrum Stewart, M.A., Ottawa. Under Mr. Stewart's direction the time service in the Government Buildings at Ottawa —a service probably unexcelled in the world—was installed and is regulated. Mr. Stewart has also made important investigations into the errors of transit observations. (R.A.S.C. JOURNAL, 1907 and 1908.)

The Secretary stated that a ballot had been taken and all the above candidates had received the required votes for election. The President then declared the candidates Fellows of the Society.

The President stated that at the last meeting of the Council a request had been presented from Hamilton that a Centre of the Society be established there. The request was favorably considered. In the absence of Dr. Marsh, on motion of Dr. C. A. Chant, seconded by R. Stewart Muir, 35 candidates, residents of Hamilton, whose names were read, were elected members of the Society. Mr. A. B. Mitchell, Faculty of Applied Science, University of Toronto, was also elected a member.

The President then left the chair, which was taken by Prof. A. T. De Lury, vice-president. Mr. Musson then gave an address upon the subject of "The Devolopment of the Stellar Universe." In the course of his address Mr. Musson reviewed the more generally accepted theories of stellar development, the main conclusion being that although there appears to be evidence of a very strong nature in favor of the theory that the transition from one type of star to another is the result of a gradual and continuous evolutionary process, still development along divergent lines should not be unexpected, and that mass and environment might be determining factors of very great importance in a star's life history. Attention was also drawn to the apparently close agreement between mathematical calculation and the results of observation, in relation to the origin and development of binary systems.

The meeting, which was largely attended, was held in the chapel of the College, and the adjoining rooms were at the Society's disposal. In one, Mr. L. Gilchrist operated an X-ray apparatus, and Mr. A. F. Miller gave demonstrations with a spectroscope how the presence of different substances is recognized in the heavenly bodies. Refreshments were served at the close of the meeting and a social hour concluded the evening.

January 26.—The following was elected a member of the Society:

Mr. Thomas Wright, 158 Amelia St., Toronto.

The paper by Mr. A. F. Miller dealt with "The Precession of the Equinoxes: its Cause and Effects." Mr. Miller explained how the equinoctial points are determined and described the progress of the celestial north pole during 13,000 years, half of the precession period. The effect of proper motions was also discussed.

E. A. D.

AT OTTAWA.

December 17. 3 P.M.—Dr. Otto Klotz presented a paper on Gravity. Dr. Klotz began by expressing the hope that although we did not yet know what gravitation is, the question would some day be answered.

After speaking of the most recent theories of the nature of matter, the atom supposed to be divided into a number of negatively-charged corpuscles, Dr. Klotz defined matter as something that we can handle, feel, see, measure, but not weigh, as to weigh bodies implies a force acting upon them, the force of gravitation. The law of gravitation was stated, and it was pointed out that, if the earth attracts a pound of sugar giving it weight, then the sugar also attracts the earth. The three fundamental units used in all physical problems, the units of length, mass and time, and those into which the former are readily converted, mass, energy and density, were stated, and it was pointed out that everything known in the universe can be placed in the three compartments of, Matter, Ether or Energy.

Mass, length and time are all readily measured or compared with similar quantities while the other units are readily derived from these.

Newton's opinion in regard to the nature of gravitation was quoted and the paper proceeded to discuss the effect of gravitation on the figure of the earth. If the earth is imagined as a rotating fluid mass, part of the influence of gravity would be counteracted by the tendency of the particles to continue in a straight line, commonly called centrifugal force, and the earth would assume the form of an ellipsoid of revolution.

Newton and Huygens, by certain assumptions, computed the ellipticity to be $\frac{1}{230}$ and $\frac{1}{579}$ respectively.

More recent calculations have been based on different assumptions as to the nature of the interior, and have been computed by Clairaut's Theorem (1743), which forms the basis of the formulæ for the reduction of pendulum observations. These observations, with actual measurements of arcs of the meridian at different parts of the earth's surface, enable the figure of the earth to be accurately determined. Conversely these measurements in conjunction with, as Laplace discussed, the precession of the equinoxes and also with the new science of Seismology, furnish a much more definite and accurate conception of the state of the interior of the earth and of the increase of density towards the centre.

The lecturer referred to the difficulty in pendulum observations, in that they were not taken on the surface of the ideal spheroid but were affected by local irregularities and by the height above mean sea-level.

Dr. Klotz spoke at some length of the results obtained in the great Trigonometrical Survey of India, as showing that the expected effect of the Himalayas in deviating the plumb-line was partly counteracted by the attraction of an invisible mass to the south.

The correction for reduction to sea-level of pendulum observations was also discussed and the various hypotheses on which these are based were explained.

Before describing the apparatus Dr. Klotz explained the final conclusions reached, that the interior of the earth along with the crust is in hydrostatic equilibrium, but that local irregularities have still some effects which are, however, confined to a shallow part of the crust.

The pendulum apparatus, a half-seconds pendulum, swinging in an air-tight case, was exhibited and the method of conducting the experiment, with the various precautions necessary, was fully and interestingly described. Dr. Klotz also developed the relation between the length and time of swinging of the simple pendulum, and gave the formulæ used in obtaining the corrections for amplitude and change of temperature.

J. S. P.

January 14, 8 P.M.—The meeting was held in the lecture room of the Carnegie Library, Dr. O. Klotz in the chair.

Mr. A. Mackenzie, Campbellton, N.B., was elected a member of the Society.

The paper for the evening was by Mr. Joseph Pope, C.V.O., the subject being "The Minor Planets."

Mr. Pope began by touching on the immensity of the subject of astronomy in general, especially as regards space and distance. By two forceful illustrations he showed the relative positions of the bodies comprised in the solar system and at the same time the complete isolation of the system from the fixed stars. A railway train running at top speed day and night would cross the solar system in 10,000 years, but would take 50,000,000 to get to *α Centauri*, the nearest fixed star. Again, if the solar system were mapped out on a scale small enough to cover Cartier Square, Ottawa, the nearest fixed star would be as far away as Russia.

He then outlined the simple observations made by the early Chaldeans and others, which led to a knowledge of the movements of the Moon, the fixed stars, and later of the planets. When the distances of the larger planets were known the following curious fact, known as Bode's law, was noted. If 4 be added to each term in the series 0, 3, 6, 12, 24, 48, 96, 192, of

which each term after the second is double of the one preceding, we obtain a series of numbers roughly proportional to the distances of the planets from the Sun, except in the case of the fifth term. The absence of any planet at this distance led to a systematic inspection of the Zodiac by the telescope, which was rewarded by the discovery of Ceres, Pallas, Vesta, Juno and of about three hundred other smaller asteroids. Later on about as many more were discovered by photography. Amongst those thus discovered was Eros, the heavenly body which comes nearer to the earth than any other except the Moon.

The theories which accounted for the existence of the asteroids were then discussed, and the lecture closed by the reading of an extract describing an imaginary trip to an asteroid.

January 28, 3 P.M.—Mr. Charles Savary, 82 James St., Ottawa, was elected a member of the Society.

Dr. W. F. King, C.M.G., read a paper on "The Occurrence of π and e in Investigations." After briefly outlining his plan of treating the subject, Dr. King gave an account of the history of the problem of determining the value of π. The earlier values found varied in accuracy from the value 3, given by the early Hindus, Babylonians, Hebrews and others, to the value 3·1416 given by the Hindus about 500 A.D. Archimedes showed that the problem was equivalent to "squaring" the circle.

It was then shown how π could be determined to any degree of accuracy by finding the areas of circumscribed and inscribed polygons, the accuracy increasing as we increase the number of sides. Vieta, adopting this method, found π correct to ten places of decimals, and also expressed π as the sum of an infinite series, thus opening up the way for the modern method of calculating it. After giving many series expressing π, and the advantages of each for rapid calculation, Dr. King stated that π had been calculated correct to 707 decimal places. It had also been shown that π is incommensurable and transcendental.

Speaking of the occurrence of π, Dr. King pointed out that it connected linear with space measurements, and hence appeared in any formula in which one was derived from the other, as for

example in expressing the area of a circle in terms of the radius, in expressing the area of a triangle in terms of two sides and an included angle. If π did not occur explicitly it was nevertheless implicitly present, thus:

$$\text{Area of triangle} = \frac{1}{2}\, ab \sin C$$
$$= \frac{1}{2}\, ab \sin \frac{\pi C}{180}$$
$$- \frac{1}{2}\, ab \left(\frac{\pi C}{180} - \frac{1}{6} \frac{\pi^3 C^3}{180^3} + \ldots \right).$$

In dealing with radiations about a point, as in statical electricity, we get the constant 4π. If a particle moves under a central force such that the area described by the radius vector varies with the time, we naturally find the time to involve π.

The constant e, on the contrary, appears where forces or processes of a cumulative nature are going on, as for example in ordinary compound interest, in the absorption of light in passing through a medium, in the theory of the hydrostatics of elastic fluids where the pressure is cumulative and its effect is a percentage effect on successive layers of the atmosphere. Another example is that of a body moving with moderate speed through a resisting medium. The loss of energy is a percentage of the total energy at any time, and we get an exponential expression for the circumstances of the motion at any time. An interesting confirmation of this theory is given by the photographic record of the gradual slowing down of the vibrator in a Bosch Seismograph. It is surprising to find that in some formulæ both π and e occur. Several examples of this were given and a reason assigned for the occurrence of both. Instances were also given in which π occurs in the course of an approximation.

C. E.

At Hamilton

Organization of the Hamilton Centre

A meeting of the Hamilton Astronomical Society was held in the "Museum" on the evening of December 15, 1908, the President, Mr. G. Parry Jenkins, F.R.A.S., in the chair.

After the adoption of the minutes of the previous meeting, the President tendered to Rev. Dr. Marsh a vote of thanks passed by the Society at that meeting for his kindness in putting in order the Bernier Telescope.

Dr. Marsh was then called upon to explain the organization and objects of the Royal Astronomical Society of Canada, which he did at some length, strongly urging the members of the Hamilton Society to abandon their charter and merge themselves into the national organization. A list of eighteen names was presented, of ladies and gentlemen, who had agreed to apply for membership in the R. A. S. C., and to these were added the names of nearly all, if not all, the members of the Hamilton Society present, making a total of thirty-five.

After a very general discussion it was moved by Mr. C. G. Milne and seconded by Mr. T. H. Wingham that, if permission be obtained to form a Centre of the Royal Astronomical Society in Hamilton, the Hamilton Astronomical Society surrender its charter and merge into the national organization.

The motion was carried unanimously.

The Rev. Dr. Marsh and Rev. Father R. E. M. Brady were appointed as delegates to meet the Council of the R.A.S.C. to make the necessary arrangements for forming a Hamilton Centre.

The following officers were then elected with the understanding that they were to be the officers of the new Centre when organized.

President of the Centre.—G. Parry Jenkins, F.R.A.S.

Vice-President.—Wm. Bruce.

Secretary.—E. H. Darling, A.M. Can. Soc. C.E.

Treasurer.—A. T. Neill.

Council.—J. J. Evel and T. H. Wingham.

The Rev. D. B. Marsh, D.Sc., F.R.A.S., then gave his illustrated lecture on the "Phenomena of the Sun's Surface." The lecture was a most instructive one, presenting the latest theories and discoveries in connection with this subject. On the motion of Mr. J. J. Evel and Mr. A. T. Neill he was tendered a hearty vote of thanks.

At a meeting of the Council of the R. A. S. C. on December 22, 1908, Rev. Dr. Marsh and Mr. G. Parry Jenkins presented the request from Hamilton for the formation there of a Centre of the Society, and on motion the request was acceeded to.

January 15, 1909.—The first meeting of the Royal Astronomical Society at Hamilton was well attended and very enthusiastic. The President, Mr. G. Parry Jenkins, was in the chair and in his opening remarks gave a brief report of the work of reorganization.

Twenty-one applications for membership were received, bringing the total up to fifty-six. The Vice-President, Mr. Wm. Bruce, invited the Society to visit his observatory on the Mountain at any time.

The Hamilton Society was fortunate in having at its first meeting Prof. C. A. Chant, Editor of the JOURNAL, who before beginning his lecture gave a brief history of the formation and growth of the R. A. S. C.

The title of lecture was "The Universe of Stars." He had with him star maps for January which he distributed among the audience. By means of a splendid series of slides it was clearly illustrated that the lucid stars are far from numberless, being about six thousand, while those made visible by a large telescope or by photography can be estimated by the hundred millions.

Several fine slides of star clusters were given and also of nebulæ showing the predominance of the spiral type. Reference was made to variable stars and the light-curve of several discussed.

In conclusion the lecturer illustrated very clearly how the composition of the stars and their velocity to or from the earth were obtained by means of the spectroscope.

Dr. Chant was given a very hearty vote of thanks on the motion of Mr. W. A. Robinson and Rev. Father Brady.

February 12.—The R. A. S. C. at Hamilton had another very successful meeting this evening in spite of many counter attractions.

Mr. John A. Paterson, K.C., M.A., Toronto, Past President of the R. A. S. C., gave a paper on "Tennyson and Astronomy,"

which, as developed by Mr. Paterson, became a most polished and poetical address.

Tennyson, as he explained, was the first poet to venture to express the wonders of science in poetry. His statements are always scientifically correct, as he spared no pains to acquaint himself thoroughly with the facts. His references to Astronomy, the science of the universe, are numerous and are among the most brilliant passages in his poems. Mr. Paterson collected these gems and wove them together by his eloquence into one of the most delightful addresses the Society has ever had.

Mr. A. T. Neill and Mr. Wm. Bruce expressed the thanks of the meeting at the close of the lecture.

At the opening of the meeting the local President, Mr. Jenkins, had thrown on the screen six or eight photographs of the Morehouse Comet. The slides were loaned to him from Professor Barnard's own collection, and showed some of the wonderful transformations which took place in that comet during the fall of 1908.

E. H. D.

NOTES FROM THE DOMINION OBSERVATORY

Astrophysics.—The new spectrograph is completed but not yet in commission, as some minor details in regard to its attachment to the telescope and in the automatic heating attachment require attention. It is expected that regular observing with the new instrument will be commenced before the end of the month. It will be fully described later, but in the meantime it may be of interest to state that preliminary tests have shown it to be by far the most rigid and stable single-prism spectrograph yet constructed. The spectrograph was attached to the telescope, which was rotated on the declination axis in the meridian until it pointed almost to the north and south horizons alternately. In these two positions comparison spectra were made adjacent to one another so that if any flexure were present (and these two positions would give the maximum amount) it would be exhibited by displacement of the lines. If there is any displacement it is certainly not measurable, and although in some parts of the spectrum there appear to be a barely noticeable discontinuity in the adjacent lines, yet when on one plate three sets were made, two with the maximum flexure and one with the spectrograph stationary, it was quite impossible to distinguish between the three. As in any practicable exposures less than a tenth of the maximum flexure could enter, it is evident that any possible systematic error due to this cause is entirely eliminated. It may be stated for comparison that the maximum flexure of the single-prism form of the spectrograph at present in use is equivalent to a velocity of upwards of 100 kms. per second.

Work on spectroscopic binaries is being actively prosecuted, about a dozen being now under investigation, and on three of these the orbits are practically completed and will be published shortly. The majority of the stars observed here are of the first

type, and the poor quality of the spectra for measurement with the small dispersion used make it necessary, for a satisfactory orbit, to obtain a large number of plates for each star. The average number used here for the orbits completed and under discussion is about 80, at least three times that employed in solar type stars, thus entailing considerable additional labor.

Solar work has been resumed after a long delay caused by the room in which the spectrograph is located having been torn up for the installation of a pump for draining the piers of the meridian instruments. The reflecting slit spoken of in previous notes has been attached and measurement of the plates for determining the solar rotation will begin immediately.

J. S. P.

THE repairs and alterations to the Transit Building have now been practically completed. The new piers, so far as can be judged at present, give every promise of stability. As mentioned before, they have been sunk several feet below their previous level, and a thorough system of drainage has been applied to the footings; the necessity for this is shown by the fact that already in the neighborhood of 1,500 gallons of water has been pumped from the cistern. A few days before the date of writing, the pit of one of the collimator piers was opened for the installation of a thermometer, and the footings were found perfectly dry, while the temperature was well above freezing point. All the piers, above the level of the floor, are protected by a layer of thick felt and surrounded with wooden casings, to prevent rapid fluctuations of temperature.

The portable transits have at last been removed from the temporary sheds in which they have been mounted ever since the occupation of the Observatory, and have been mounted in the new Transit Room, an occasion which was hailed with considerable pleasure by the observers, as many of the previous discomforts will now be removed.

R. M. S.

The Seismograph—Bosch Photographic, 200 grammes—Magnification, 120.—The following are the earthquakes recorded here since the last notes were sent :—

December 12	N-S Component	E-W Component
	h m s	h m
First trace of Waves	13 43 40 G.M.T.	13 44 G.M.T.
Long Waves		13 46
" "	13 57	13 57
End	14 26	14 16.

Microseisms were present and the First Preliminary Tremors (1st P. T.) are not recognizable.

December 28	N-S Component	E-W Component
	h m s	h m s
1st P. T.	4 31 04 G.M.T.	4 31 04 G.M.T.
2nd P. T.	4 39 47	4 39 42
Maximum	4 56 30	5 00
End	9 20	6 10

The long waves from $4^h 50^m$ to $5^h 15^m$ are nearly all of 16" period.

The computed distance based on the above data from Ottawa to the centre of disturbance agreed within 50 miles of the actual, when it was subsequently learned that a very destructive earthquake had occurred about the Straits of Messina. The record of this disastrous quake is not as marked in amplitude, *i.e.*, in absolute movements of the earth particles transmitting the waves as one might infer from the catastrophe, although we must not forget that the destruction of life is no criterion for comparison in earth movements and adjustments of the crust to relieve the strains that are continually present. The public measures the violence of earthquakes by the destruction of life and property, while the geophysicist measures it by the earth movement and acceleration produced.

The amplitude of the San Francisco quake in 1906 was many times greater than that of the recent Calabrian quake. Of course, the former was only a little over half as distant as the latter. The less amplitude is most likely due to the shallow depth of the hypocentre ; to this would be added the less dense and elastic nature of the propagating matter there. To a less degree the

amplitude would be influenced by the constitution of the material along the path of the propagating wave, as differing from that of the San Francisco path. From records here of Italian quakes, or rather from want of records here for seismic disturbances in Italy, the conclusion has already been arrived at, that Italian earthquakes are not deep-seated. It took 11 minutes for the waves to travel from Sicily to Ottawa, which is at the rate of 660 km. per minute, or 11 km. or 7 miles per second.

December 28	N-S Component	E-W Component
	h m	
1st P. T.	23 22 05	
End	24 00	

No other phases recognizable.

January 12, 1909.	N-S Component	E-W Component
	h m s	h m s
1st P. T.	0 04 35 G.M.T.	0 04 38 G.M.T.
End	0 22	0 22

On January 11 an earthquake was reported from Vancouver and other places about the Straits of Juan de Fuca at $3^h\,45^m$ P.M. which would be $23^h\,45^m$ G.M.T. or nearly 20 minutes before the above record. The time of transmission of an earthquake wave from Vancouver to Ottawa would be about 6 minutes, so that there are 14 minutes unaccounted, if the time of the Press despatch is correct, and provided the seismogram is of that quake.

Two smaller quakes followed the same day: one showing itself at $10^h\,26^m$ G.M.T., ending at $10^h\,37^m$, the other appearing at $12^h\,30^m$ G.M.T., ending at 12:55. The seismogram has the appearance of surface waves, showing periods from 12s to 16s.

January 21	N-S Component	E-W Component
	h m s	h m s
First trace of Waves	21 43 G.M.T.	21 43 G.M.T.
Maximum	21 47 30	21 48 40
End	22 05	22 00

Individual phases are not recognizable in the above.

January 23	N-S Component	E-W Component
	h m s	h m s
1st P. T.	3 01 13 G.M.T	3 01 13 G.M.T.
2nd P. T.	3 11 42	3 11 42
P. P.	3 32 (period 24s)	3 32 (per. 22s)
Maximum	3 35	3 37
End	4 40	4 50.

The epicentre is estimated at a distance of 9,300 km.

The following table is of interest. It has been compiled from data received from various stations.

It will be observed that between the distances 1,000 to 9,550 km. the velocity for both the first preliminary and second preliminary varies or increases nearly as the distance, that is, the velocities when plotted with the distances as abscissæ, fall very closely along a straight line.

CALABRIAN EARTHQUAKE, DECEMBER 28, 1908.

Time of occurrence taken as 4h 20m G.M.T. (Professor Rizzo). Time data below obtained from reports from respective earthquake stations. Distances taken from our 30-inch globe.

P, *S*, *L* are respectively the time of arrival of the First Preliminary, the Second Preliminary and the Long waves.

Place	Distance	Middle Ordinate to Chord	P	S	L	Velocity per Min.			$\frac{S}{P}$
						P	S	L	
	km.	km.	h m s	h m s	h m s	km.	km.	km.	
Ottawa	7200	992	4 31 04	4 39 42		651	365		·56
Washington	7650	1116	4 31 23	4 40 30		672	373		·56
Tiflis	2550	128	4 25 33	4 29 50	4 35 20	458	259	166	·57
Cartuja	1700	56	4 23 35	4 26 40	4 27 50	474	255	217	·54
Sarajevo	700	10	4 21 51	4 23 09	4 23 54	378	222	180	·59
Belgrade	850	14	4 22 09	4 23 11	4 24 12	395	267	202	·68
Laibach	900	16	4 22 18	4 23 33	4 24 16	391	254	211	·65
Vienna	1100	24	4 22 55	4 25 17	4 26 16	377	208	175	·55
Krakau	1400	38	4 23 23	4 25 59	4 26 48	413	234	206	·56
Hamburg	1750	60	4 24 16	4 27 18	4 28 12	410	240	213	·58
Aachen	1600	50	4 23 53	4 26 38		412	241		·58
Toronto	7500	1075	4 31 12	4 39 48	5 00 00	670	379	187	·57
Victoria	9550	1709	4 33 12	4 43 36	5 06 36	723	405	205	·56
						Mean		196·2	
						Per sec.		3·27	

The ratio $\frac{S}{P}$ is pretty constant, with the exception of the three stations Sarajevo, Belgrade and Laibach, which are all less than 1,000 km. from the epicentre, and for which the ordinates to the chords are small, from 10 to 16 km., not reaching to the supposed layer of isostatic adjustment.

The degree of accuracy of the time element in the records for deducing velocities is of far more consequence for close

stations than for very distant ones. However, in the above, which comprise all the data available at the moment, there does not appear to be any serious discrepancy in the reading of the various seismograms.

The *L* waves show themselves conspicuously as being propagated over the same medium for all stations, that is, along the surface, by having the same velocity. Thus the velocity to Krakau (Cracow) is the same as for Victoria, seven times as distant. Although there are some variations in the velocity of the surface waves, they are wholly independent of the distance.

O. K.

THREE EXCEPTIONAL EARTHQUAKES RECORDED AT TORONTO ONT. AND VICTORIA, B.C.

By J. Young

We have no reports as to where the earthquake shock of October 13 took place, but the approximate distance from Toronto would be 4,600 km., and from Victoria 4,425 km. The disturbance of November 30 was centred in Queen Charlotte Islands. A Press despatch from Skidegate states that the shock occurred at 1.30 o'clock in the afternoon of the 30th. The Indians were much more alarmed by the occurrence than the white people. Not even in Indian tradition is there anything to indicate that the Islands ever before were visited by an earthquake. and the shock was something the aborigines were at a loss to account for.

The earthquake lasted seven seconds and apparently travelled from north to south.

The disastrous Calabrian earthquake of December 28 was well recorded by both Toronto and Victoria instruments. Although the amplitudes were not large, the booms oscillated very rapidly at times. Press accounts concerning the appalling earthquake disaster in the three provinces of Southern Italy, say that the tragedy is without parallel in the Christian era, loss of life from 150,000 to 200,000. Towns and villages have been wiped out and in outlying districts the number of dead alone exceed 30,000.

Two-thirds of Messina was destroyed by the earthquake and a tidal wave which followed. The sea rose and a tremendous wave wrecked many vessels and swept over the lower portions of Messina.

The preliminary tremors from this earthquake reached Toronto at $4^h\ 31{\cdot}2^m$ G.M.T. and Victoria at $4^h\ 33{\cdot}2^m$. The large

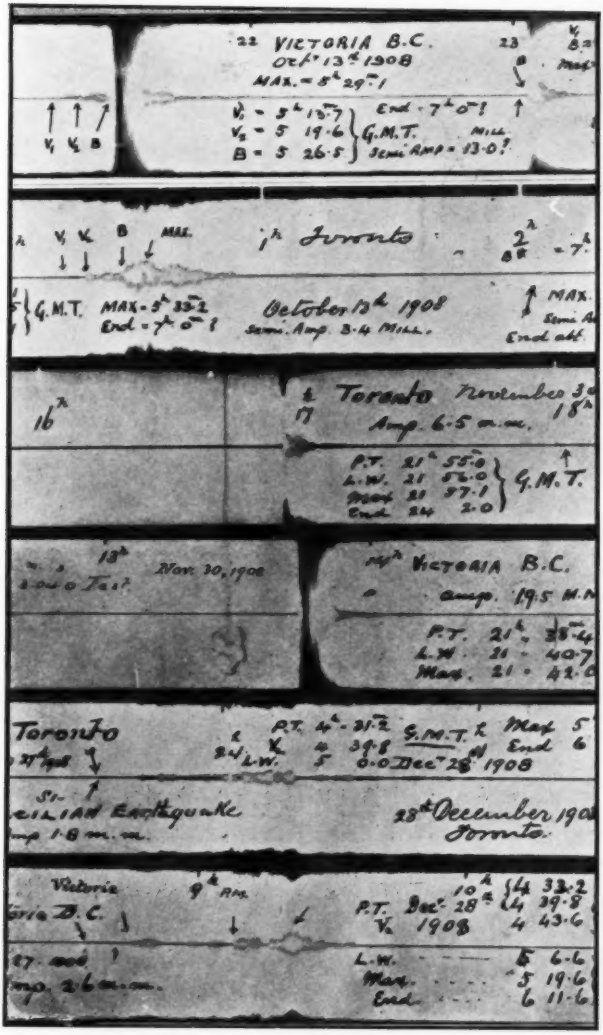
waves arrived at Toronto $4^h\ 39{\cdot}8^m$, and at 4·52 another series of larger waves appeared. From 5·03 to 5·15 short phases, motion of ampiltudes 1·55 mm., were well recorded by the Toronto instrument, and are shown again, but on a smaller scale, from 5·21 to 5·30 and then a gradual tailing-off, the last signs of the earthquake record disappearing at $6^h\ 45{\cdot}5^m$. The maximum motion was registered at $5^h\ 2{\cdot}1^m$. The amplitude was 1·8 mm., on the Victoria trace. There was a blurred thickening of the line which has been taken as the beginning of preliminary tremors at $4^h\ 33{\cdot}2^m$, and at $4^h\ 43{\cdot}6^m$ a more decided record is shown which may be the commencement of large waves. At $5^h\ 6{\cdot}6^m$ a noticeable increase in the vibrations is seen, the maximum occurring at $5^h\ 19{\cdot}6^m$, and the end at $6^h\ 11{\cdot}6^m$, the amplitude being 2·6 mm.

In taking the velocities of waves, allowance has been made of a difference of six hours in time between Messina and our stations. Accepting the time of the first shock at Messina as 5·15, the speed of the preliminary tremors to Toronto would be 4·4 km. per second and to Victoria 4·8 km.

METEOROLOGICAL OFFICE,
TORONTO, CANADA.

[In next issue will appear a List of earthquake records at Toronto and Victoria for July–December, 1908].

PLATE VII.



Records by the Milne Seismographs at Toronto and Victoria, B. C., of three marked Earthquakes. (2/3 original size).

ASTRONOMICAL NOTES

THE January number of *Monthly Notices of the Royal Astronomical Society* contains a paper by Prof. Simon Newcomb on "Fluctuations of the Moon's Mean Motion," in which he says: "With the aid of my assistant Dr. Frank E. Ross, I have brought to a completion a study of the Moon's mean motion based on observations having an extreme range in time of about 2600 years. The data of observation are as follows:—

"1. The eclipses of the Moon found in Ptolemy's Almagest, observed between B.C. 720 and A.D. 134.

"2. Observations of eclipses by the Arabian astronomers, extending from 829 to 1004.

"3. Observations of eclipses of the Sun and of occultations of stars by the Moon made by Gassendi, Hevelius, and others, from 1620 to 1680.

"4. Observations of occultations of stars from 1670 until the present time. . . . .

"Before 1750 the observations are not sufficiently continuous, numerous, and accurate to show any fluctuation with certainty. The first minor fluctuation fairly well shown began about 1760. During the years 1765-1784 the Moon ran ahead about 1″. Then the excess of motion ceased, and became temporarily reversed. Since 1820 the motion has been marked by rapid fluctuations, which can be so well traced on the plate that no description is necessary.

"Since what is actually observed is neither the acceleration nor the speed of motion, but changes of the longitude itself, of which these quantities are respectively the second and the first derivatives as to the time, it is not possible from the observations to make any approach to an accurate estimate of the accelerating or retarding forces. The most we can say is that these varying forces are sufficient to bring about a change of annual motion amounting to between 0″·5 and 1″·0 by acting during a period of perhaps from 4 to 6 years. . . . .

"I regard these fluctuations as the most enigmatical phenomenon presented by the celestial motions, being so difficult to

account for by the action of any known causes, that we cannot but suspect them to arise from some action in nature hitherto unknown. . . . .

"One general result of the present state of things is that we cannot draw any precise conclusions from a discussion of the Moon's motion in longitude, how refined soever we make it. For example, it is impossible to derive from observation the accurate coefficient of the 18·6-year nodal inequality in longitude, owing to the varying fluctuation.

"It is also not possible to predict the future motion of the Moon with precision. If we require our ephemerides of the Moon's longitude to be as exact as possible, we must correct the tabular mean longitude from time to time by observations."

AT a recent meeting of the British Astronomical Association "Dr. David Smart read a paper on Halley's Comet in 1910. He said that at the beginning of 1910 Halley's comet would be an evening star, and would remain so until lost in the Sun's rays about the first week in March. It would, he hoped, be a naked-eye object, but as it had not yet been photographed, he had some doubts. On March 23 the comet would pass about six degrees north of the Sun; it would then become a morning star. By April 20 it would be about two hours west of the Sun, and would be rapidly getting brighter, as it would be near perihelion and fast approaching the Earth, from which it would be distant about 94,000,000 miles. On May 8, the day of the Tasmanian total eclipse of the Sun, the comet would be near 41 *Piscium*, and in southern latitudes would rise about three hours before the Sun. It would not, however, be visible during totality, as it would have set some 20 minutes before. It would then be about 34,000,000 miles from the Earth. On the 14th it would rise more than an hour before the Sun, and should be a conspicuous object in the morning twilight. So quick would be the comet's motion about that time that by midnight of the 18th it would be nearly two hours east of the Sun, about halfway between *β Tauri* and *β Orionis*. On that day it would make its nearest approach to the Earth, from which it would be 12,500,000 miles away. The

tail would extend across the southern part of *Gemini*, and should be a splendid object. A gibbous Moon would unfortunately be a great disadvantage during that time. The comet would be at its descending node on the ecliptic on the morning of May 16, and the Earth would pass through the node on the comet's orbit about two and a half days later. Meteors, if any, cast off by the comet would be most likely to be seen within a few days of May 5. He made the radiant R.A. $22^h\ 57^m$, Dec. $+4°$."—*The Observatory*, February, 1909, p. 89.

THE same number of *The Observatory* contains an account of the Annual Meeting of the Royal Meteorological Society. Dr. H. R. Mill "devoted his Presidential Address to 'Some Aims and Efforts of the Society in its Relation to the Public and to Meteorological Science.' . . . He stated that we now stand at a very important point in the history of meteorology, which bids fair to expand in interest and importance in the 20th century, as chemistry did in the 19th, and from the same cause—increasing necessity of applying its principles to practical ends. The standpoint of the meteorologist to-day is different from that of 50 or even of 20 years ago. Then the only department in which much general interest could be expected was climatology, the study of the average conditions of the atmosphere at different places. Much remains to be done in that department, but the main interest is being diverted from the study of the air 4 feet above the ground, on the study of which climatology has been based, to the vast expanse of the upper atmosphere miles above the abode of man."

IT is announced that Mr. H. F. Newall of the Cambridge Observatory is to be appointed Professor of Astrophysics in the University of Cambridge.

WHEN the making of the great disk of glass, 100 inches in diameter, for the Solar Observatory at Mt. Wilson was nearly finished, flaws were discovered in it of so serious a nature as to render it valueless. Professor Hale has decided that a new disc will be necessary. This will delay the completion of the instrument for some time.

J. R. C.

CONSTELLATIONS ON THE MERIDIAN IN MARCH

Argo (the Ship) occupies a large space in the southern hemisphere, but only a small part of it can be seen in Canada. It is S.E. of Canis Major and may be known by the stars in the prow and deck of the ship. If a straight line joining Betelgeuse and Sirius be produced to the S.E. 18° it will point out Naos, a star of the second magnitude, in the rowlock of the ship. This star is in the S.E. corner of the Egyptian x, and the large equilateral triangle made by itself and with Sirius and the Dove. When on the meridian it is about 8° above the S. horizon. It comes to this point about the 3rd of March, half an hour after Procyon, and continues visible but a few hours. The constellation contains 64 stars, of which two are of the first magnitude, four of the second and nine of the third, most of them too far south to be seen here.

Cancer is now the fifth constellation and fourth sign of the Zodiac. It is situated in the ecliptic between Leo on the E. and Gemini on the W. It contains 83 stars, one of which is of the third and seven of the fourth magnitude. Some place the first-mentioned star in the same class with the other seven, and consider none greater than the fourth magnitude.

CONSTELLATIONS ON THE MERIDIAN IN APRIL

Leo is one of the most brilliant constellations at this time of the year, and contains an unusual number of very bright stars. It is situated next E. of Cancer and directly S. of Leo Minor and the Great Bear. Leo is the fifth sign, and the sixth constellation of the Zodiac. The mean right ascension of this extensive group is 10^h. Its centre is therefore on the meridian on the sixth of April. Its western outline, however, comes to the meridian on the 18th of March, while its eastern limit does not reach it before the 3rd of May. The constellation contains 95 stars; one of the first, one of the second, six of the third, and fifteen of the fourth

magnitude, the principal star being Regulus, which is situated very close to the ecliptic.

Leo Minor contains 53 stars, including only one of the third and five of the fifth magnitude. Its mean right ascension is the same with that of Regulus and comes on the meridian at the same time on the 6th of April.

Sextans (the Sextant) contains 41 very faint stars including only one of the fourth magnitude. It is situated very near the equinoctial, 18° S. of Regulus and also comes to the meridian on the 6th of April.

Hydra (the Water-Serpent) is an extensive constellation, winding from E. to W. in a serpentine form, over a space of more than 100 degrees in length. It lies south of Cancer, Leo and Virgo, and reaches almost from Canis Minor to Libra. It contains sixty stars, including one of the second magnitude, three of the third, and twelve of the fourth. The head of Hydra may be distinguished by means of four stars of the fourth magnitude, 2½° and 4° apart, situated 6° S. of Acubens, and forming a rhomboidal figure. The three upper stars in this cluster form a small arch, and may be known by two very small stars just below the middle one, making with it a very small triangle. The three western stars in the head also make a beautiful little triangle. The eastern star in this group, *Zeta*, is about 6° directly S. of Acubens, and culminates at the same time.

The Cup (also called the Crater) may easily be distinguished by means of six stars of the fourth magnitude, which form a beautiful crescent, or semicircle, opening to the W. The centre of the group is about 15° below the equinoctial, and directly S. of the hinder feet of Leo. The crescent form of the stars in the cup is so striking and well defined, when the Moon is absent, that no further description is required to enable one to find it. Its centre arrives on the meridian about two hours after Alphard, on the same evening; and consequently, it culminates at 9 o'clock in one month's time after Alphard does.

A Few Variable Stars Visible During March–April

λ *Tauri*	Mag. from	3·3	to	4·2	Period	d 3	h 22	m 52·2
α *Orionis*	" "	1	"	1·4	"	Irr.		
η *Geminorum*	" "	3·2	"	4·2	"	231·4		
ζ "	" "	3·8	"	4·3	"	10	3	41·5
R Canis Majoris	" "	5·7	"	6·3	"	1	3	15·8
R Leonis	" "	4·6	"	10·5	"	312·8		
χ *Cygni*	" "	4·5	"	13·5	"	406·0		

Some Colored Double Stars Visible During March–April

α *Canum Venat.*	Mag. =	3·2 and	5·7	Golden, Lilac
32 *Eridani*	"	4·7 "	7	Topaz, Bright Green
ι *Cancri*	"	4·5 "	5	Pale Orange, Blue
o *Cygni*	"	4·3 "	7·5, 5·5	Yellow, Blue
24 *Coma Berenice*	"	5·6 "	7	Orange, Lilac
2 *Canum Venat.*	"	6 "	9	Golden, Azure
52 *Cygni*	"	4·6 "	9	Orange, Blue
κ *Geminorum*	"	3·8 "	9	Orange, Blue
ρ *Orionis*	"	5·1 "	9	Orange, Blue
23 *Orionis*	"	5·4 "	7	White, Blue
17 *Virginis*	"	6·5 "	7	Rose

Meridian Passage of the Principal Planets During March and April

LOCAL MEAN TIME

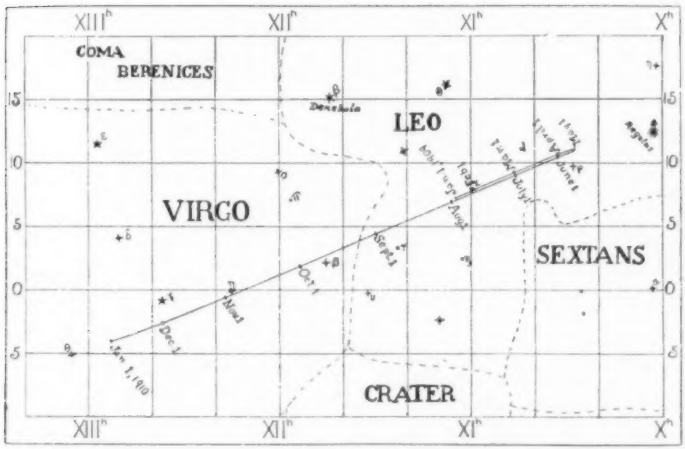
	For March 15		For April 15
Mercury	10.31 a.m.		11.36 a.m.
Venus	11.30 a.m.	{ Aquarius } { Pisces }	11.50 a.m.
Mars	7.27 a.m.	[See accompanying map]	6.54 a.m.
Jupiter	11. 8 p.m.	(Leo)	8.56 p.m.
Saturn	1.13 p.m.	(Pisces)	11.25 a.m.
Uranus	7.59 a.m.	(Sagittarius)	6. 0 a.m.
Neptune	7.23 a.m.	(Gemini)	5.29 a.m.

Mars

Mars is now in Sagittarius and rises about 2 A.M. It is not at present well placed for observation, but as it will soon be, a map showing its path among the stars is given. Mars will be a beautiful object in 1909, on September 24, its distance from the earth being but 36,200,000 miles.

Saturn

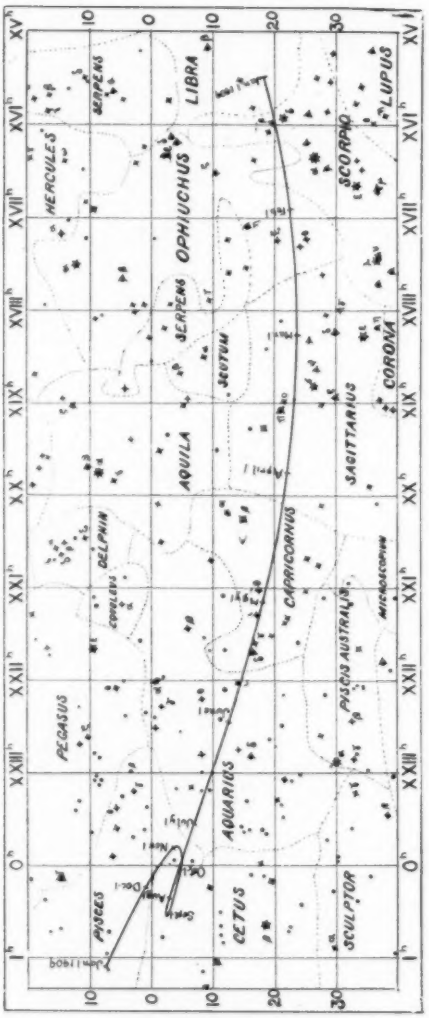
Saturn has been continually approaching the Sun, and on April 3 it will be in conjunction with it. After this the planet will be a morning star.



PATH OF JUPITER AMONGST THE STARS IN 1909.

Jupiter

Jupiter is now well placed for observation. It is retrograding and will continue to do so until May 1, at which time it will be only about 6° from Regulus. The path of the planet is shown in the accompanying map, and the observable transits and eclipses of the satellites are given on page 81.



PATH OF MARS AMONGST THE STARS IN 1909.

ECLIPES AND TRANSITS OF THE SATELLITES OF JUPITER

E = eclipse, O = occultation, T = transit, S = shadow, D = disappearance, R = re-appearance, I = ingress, e = egress. Eastern Standard Time.

MARCH

d	h	m			d	h	m			d	h	m		
1	7	50	II.	TI	**11**	15	58	I.	OD	**21**	9	28	I.	TI
	7	53	II.	SI	**12**	13	17	I.	TI		9	58	I.	SI
	10	40	II.	Te		13	35	I.	SI		11	47	I.	Te
	10	45	II.	Se		14	36	III.	TI		12	17	I.	Se
3	17	7	I.	TI		15	36	I.	Te		12	22	IV.	OR
	17	12	I.	SI		15	48	III.	SI		13	10	IV.	ED
4	14	14	I.	OD		15	54	I.	Se	**22**	9	23	I.	ER
4	16	38	I.	ER	**13**	6	56	IV.	Se		14	34	II.	TI
	18	5	IV.	OD		10	24	I.	OD		15	38	II.	SI
5	11	20	III.	TI		13	0	I.	ER	**23**	7	28	III.	OD
	11	33	I.	TI	**14**	7	43	I.	TI		13	1	III.	ER
	11	41	I.	SI		8	4	I.	SI	**24**	9	37	II.	OD
	11	49	III.	SI		10	2	I.	Te		13	35	II.	ER
	13	52	I.	Te		10	23	I.	Se	**26**	7	47	II.	Se
	14	0	I.	Se	**15**	7	29	I.	ER	**27**	13	54	I.	OD
	14	41	III.	Te		12	19	II.	TI	**28**	11	14	I.	TI
	15	17	III.	Se		13	3	II.	SI		11	53	I.	SI
6	8	40	I.	OD		15	9	II.	Te		13	32	I.	Te
	11	6	I.	ER		15	54	II.	Se		14	12	I.	Se
	15	57	II.	OD	**16**	9	2	III.	ER	**29**	8	20	I.	OD
7	8	18	I.	Te	**17**	7	21	II.	OD		11	18	I.	ER
	8	28	I.	Se		11	0	II.	ER		14	19	IV.	TI
8	10	4	II.	TI	**19**	15	2	I.	TI	**30**	7	59	I.	Te
	10	28	II.	SI		15	30	I.	SI		8	40	I.	Se
	12	54	II.	Te	**20**	12	9	I.	OD		10	50	III.	OD
	13	19	II.	Se		14	55	I.	ER	**31**	11	55	II.	OD
10	8	24	II.	ER	**21**	8	17	IV.	OD		16	11	II.	ER

APRIL

d	h	m			d	h	m			d	h	m		
2	7	31	II.	SI	**10**	7	45	III.	SI	**20**	12	6	I.	SI
	8	51	II.	Te		11	9	III.	Se		13	22	I.	Te
	10	22	II.	Se	**11**	8	4	II.	ER		14	24	I.	Se
3	7	10	III.	Se		14	47	I.	TI	**21**	8	10	I.	OD
	15	40	I.	OD	**12**	11	55	I.	OD		11	30	I.	ER
4	13	0	I.	TI		15	6	I.	ER	**22**	7	50	I.	Te
	13	48	I.	SI	**13**	9	14	I.	TI		8	53	I.	Se
	15	19	I.	Te		10	11	I.	SI	**23**	13	8	II.	TI
6	7	27	I.	TI		11	33	I.	Te	**24**	11	16	III.	TI
	8	16	I.	SI		12	30	I.	Se	**25**	8	15	II.	OD
	9	46	I.	Te	**14**	9	35	I.	ER		13	16	II.	ER
	10	35	I.	Se	**15**	9	46	IV.	Te	**27**	7	27	II.	Se
	14	15	III.	OD		14	41	IV.	SI		12	53	I.	TI
7	7	13	IV.	ED	**16**	10	43	II.	TI		14	1	I.	SI
	7	41	I.	ER		12	43	II.	SI	**28**	8	53	III.	ER
	11	7	IV.	ER		13	34	II.	Te		10	1	I.	OD
	14	16	II.	OD	**17**	7	39	III.	TI		13	25	I.	ER
9	8	21	II.	TI		11	6	III.	TE	**29**	8	29	I.	SI
	10	7	II.	SI		11	44	III.	SI		9	40	I.	Te
	11	12	II.	Te	**18**	10	40	II.	ER		10	48	I.	Se
	12	58	II.	Se	**19**	13	43	I.	OD	**30**	7	54	I.	ER
10	7	33	III.	Te	**20**	11	3	I.	TI					

At Greenwich Mean Noon
MARCH

Date 1909	Day of Year	The Sun's Right Ascension	The Sun's Declination	Equation of Time (Subtract from Mean Time)	Sidereal Time
		h m s	° ′ ″	h m	h m s
Mon. 1	60	22 47 12·00	S. 7 42 58·3	12 36·34	22 34 35·65
Thur. 4	63	22 58 24·38	6 34 14·8	11 59·07	22 46 25·31
Sun. 7	66	23 9 32·55	5 24 42·5	11 17·58	22 58 14·97
Wed. 10	69	23 20 37·12	4 14 31·5	10 32·50	23 10 4·62
Sat. 13	72	23 31 38·71	3 3 51·7	9 44·43	23 21 54·28
Tues. 16	75	23 42 37·89	1 52 52·5	8 53·95	23 33 43·94
Fri. 19	78	23 53 35·23	0 41 43·8	8 1·63	23 45 33·60
Mon. 22	81	0 4 31·22	N. 0 29 24·2	7 7·96	23 57 23·26
Thur. 25	84	0 15 26·28	1 40 20·9	6 13·36	0 9 12·92
Sun. 28	87	0 26 20·87	2 50 56·0	5 18·29	0 21 2·58
Wed. 31	90	0 37 15·52	4 0 59·7	4 23·28	0 32 52·24

75th Meridian Time, Hours numbering from Midnight

		Planetary Phenomena	Minima of Algol	Configuration of Jupiter's Satellites at 0h
			h m	
	Mon. 1	18h 32m ☌ ♆ ☾, ♆ 2° 37′ S.		432○1
	Tues. 2		10 44	421○3
	Wed. 3			4○123
	Thur. 4	14h 8m ☿ in Aphelion.		41○23
	Fri. 5	21h 8m ☿ in ♉.	7 33	2421○4
☽	Sat. 6	4h 49m ☌ ♃ ☾, ♃ 3° 42′ S.; 21h 55m Full Moon.		32○14
	Sun. 7			31○24
	Mon. 8		16 22	213○14
	Tues. 9	14h 8m ☿ Greatest Elong. W. 27° 26′.		21○34
	Wed. 10			○2134
	Thur. 11		1 10	1○234
	Fri. 12			2○134
	Sat. 13		21 59	324○●
☾	Sun. 14	22h 41·7m Last Quarter.		341○2
	Mon. 15			43○21
	Tues. 16	3h 8m ☿ in Aphelion; 9h 55m ☌ ♂ ☾, ♂ 1° 26′ N.	18 47	421○3
	Wed. 17	[21h 18m ☌ ♅ ☾, ♅ 2° 4′ N.		4○213
	Thur. 18			41○23
	Fri. 19	18h 27m ☌ ☿ ☾, ☿ 3° 5′ N.	15 36	42○13
	Sat. 20	19h 52m ☌ ♀ ☾, ♀ 3° 52′ N.		4321○
☉	Sun. 21	1h ☉ enters ♈, Spring commences. 15h 11·3m New		31○2●
	Mon. 22	6h 38m ☌ ♄ ☾, ♄ 2° 41′ N. [Moon.	12 24	3○214
	Tues. 23			21○4●
	Wed. 24			○134●
	Thur. 25	18h ♆ stationary.	9 13	1○234
	Fri. 26	16h ☌ ♂ ♇, ♂ 0° 18′ S.; 22h ☿ Greatest Hel. Lat. S.		2○134
	Sat. 27			231○4
☽	Sun. 28	11h 48·7m First Quarter.	6 02	213○24
	Mon. 29	0h 22m ☌ ♆ ☾, ♆ 2° 51′ S.		3○412
	Tues 30			241○●
	Wed. 31		2 51	4○13●

Key to Symbols.—☌ Conjunction; ☍ Opposition; □ Quadrature; ☊ Ascending Node; ☋ Descending Node; ☉ Sun; ☿ Mercury; ♀ Venus; ♁ Earth; ♂ Mars; ♃ Jupiter; ♄ Saturn; ♅ Uranus; ♆ Neptune.

At Greenwich Mean Noon

APRIL

Date 1909	Day of Year	The Sun's Right Ascension	The Sun's Declination	Equation of Time Subt'd from / Added to Mean Time	Sidereal Time
		h m s	° ′ ″	m s	h m s
Thur. 1	91	0 40 53·84	N. 4 24 12·2	4 5·05	0 36 48·79
Sun. 4	94	0 51 49·43	5 33 19·4	3 10·98	0 48 38·45
Wed. 7	97	1 2 46·40	6 41 33·7	2 18·29	1 0 28·11
Sat. 10	100	1 13 45·33	7 48 46·4	1 27·56	1 12 17·77
Tues. 13	103	1 24 46·77	8 54 49·0	0 39·34	1 24 7·43
Fri. 16	106	1 35 51·21	9 59 32·7	0 5·88	1 35 57·09
Mon. 19	109	1 46 59·03	11 2 48·4	0 47·72	1 47 46·75
Thur. 22	112	1 58 10·53	12 4 26·4	1 25·89	1 59 36·42
Sun. 25	115	2 9 25·94	13 4 17·0	2 0·14	2 11 26·08
Wed. 28	118	2 20 45·51	14 2 10·7	2 30·24	2 23 15·74
Sat. 31	121	2 32 9·53	14 57 58·9	2 55·88	2 35 5·41

75th Meridian Time, Hours numbering from Midnight

Planetary Phenomena

			Minima of Algol	Configuration of Jupiter's Satellites at 23h
			h m	
	Thur. 1			4 1 ○ 2 3
	Fri. 2	4h 30m ☌ ♃. ☾. ♃ 3° 45′ S.	23 39	4 2 ○ 1 3
	Sat. 3	6h ☌ ♄ ☉		4 2 3 1 ○
	Sun. 4	13h □ ♀ ☉		4 3 ○ 1 2
☹	Mon. 5	15h 28·4m Full Moon: 12h ♀ Greatest Hel. Lat. S.	20 27	4 3 ○ 2 ●
	Tues. 6			2 4 3 1 ○
	Wed. 7			2 ○ 4 1 3
	Thur. 8		17 16	1 ○ 2 4 3
	Fri. 9	11h ☌ ♀ ♄. ♀ 0° 58′ N.		♃ ○ 1 3 4
	Sat. 10			2 1 3 ○ 4
	Sun. 11	8h □ ♅ ☉.	14 5	3 ○ 1 2 4
	Mon. 12	[16h ☌ ♀ ♄. ♀ 0° 39′ N.		3 1 ○ 2 4
☾	Tues. 13	9h 30·2m Last Quarter: 5h 11m ☌ ♅ ☾. ♅ 2° 20′ N.		♃ 2 3 ○ 4
	Wed. 14	1h 43m ☌ ♂ ☾. ♂ 2° 29′ N.	10 53	2 ○ 1 3 4
	Thur. 15			1 4 ○ 2 3
	Fri. 16			♃ 4 ○ 1 3
	Sat. 17		7 42	4 2 1 3 ○
	Sun. 18	23h 43m ☌ ♄ ☾. ♄ 2° 33′ N.		4 3 ○ 2 1
☹	Mon. 19	23h 51m New Moon; 17h 36m ☌ ♀ ☾. ♀ 3° 28′ N.		4 3 1 ○ 2
	Tues. 20	[17h 51m ☌ ♀ ☾. ♀ 3° 7′ N.; 22h ☌ ♀ ♃.	4 30	♃ 4 3 2 ○
	Wed. 21	18h ☌ ♀ ☉ Superior. [♀ 0° 22′ N.		4 2 ○ 3 ●
	Thur. 22			4 1 ○ 2 3
	Fri. 23		1 19	4 ○ 2 1 3
	Sat. 24	12h ♀ in ☊.		2 1 ○ 3 4
	Sun. 25	8h 45m ☌ ♆ ☾. ♆ 3° 5′ S.: 19h ♅ Stationary.	22 8	3 ○ 1 4 ●
	Mon. 26			3 1 ○ 2 4
☽	Tues. 27	3h 36·2 First Quarter;		3 2 ○ 1 4
	Wed. 28	12h ☌ ♀ ☉ Superior;	18 56	2 ○ 3 4 ●
	Thur. 29	2h ♀ in Perihelion; 8h 37m ☌ ♃. ☾. ♃ 3° 59′ S.		1 ○ 2 3 4
	Fri. 30			○ 1 2 3 4

For Jupiter's Satellites, the Circle ○ represents the disc of the Planet; ♃ signifies that the Satellite is on the disc, ● signifies that the satellite is behind the disc or in the shadow. Configurations are for an inverting telescope.

SUMMARY REPORT OF THE WEATHER IN CANADA

DECEMBER, 1908

Temperature.—The temperature was above the average at Dawson City, in the Yukon Territory, below in British Columbia and in the northern portions of Alberta and Saskatchewan, above elsewhere in the Western Provinces and over most of the Ontario Peninsula, average or below in the other portions of Ontario and below average in Quebec and the Maritime Provinces.

The chief positive departures were: Dawson City, Prince Albert and Qu'Appelle, 2 degrees; Winnipeg, 3 degrees; and the chief negative departures: Kamloops, 6 degrees; Rockliffe, 4 degrees; Quebec, 3 degrees; Chatham, N.B., 4 degrees, Charlottetown, 2 degrees.

For the highest and lowest temperatures at various stations see the accompanying table.

Precipitation.—In the Yukon Territory, Dawson City recorded 22 inches of snow, which is twice as much as the average quantity. In British Columbia the precipitation was everywhere less than usual, varying from one-tenth of an inch at Kamloops, to 1·55 inches at Victoria. In Alberta the negative departure was from 59 to 82 per cent. In Saskatchewan, in the vicinities of Prince Albert and Qu'Appelle, the snowfall appears to have been much more than the general amount, but elsewhere in the Province there was a deficiency equivalent to from 70 to 88 per cent. In Manitoba the deficit was from 36 to 70 per cent. In Ontario, over Lake Superior and from the Ottawa Valley eastward, there was a marked positive departure, while in the peninsula the negative departure was equal to 2·66 inches at Parry Sound; 1·00 inch at Kingston, and less elsewhere. In Quebec the average was well exceeded, except apparently in the extreme eastern portion. Montreal recorded a positive departure of more than 2·00 inches. In the Maritime Provinces the precipitation was above the average, the positive departures varying from ·40 of an inch at St. John, to 2·50 inches at Halifax.

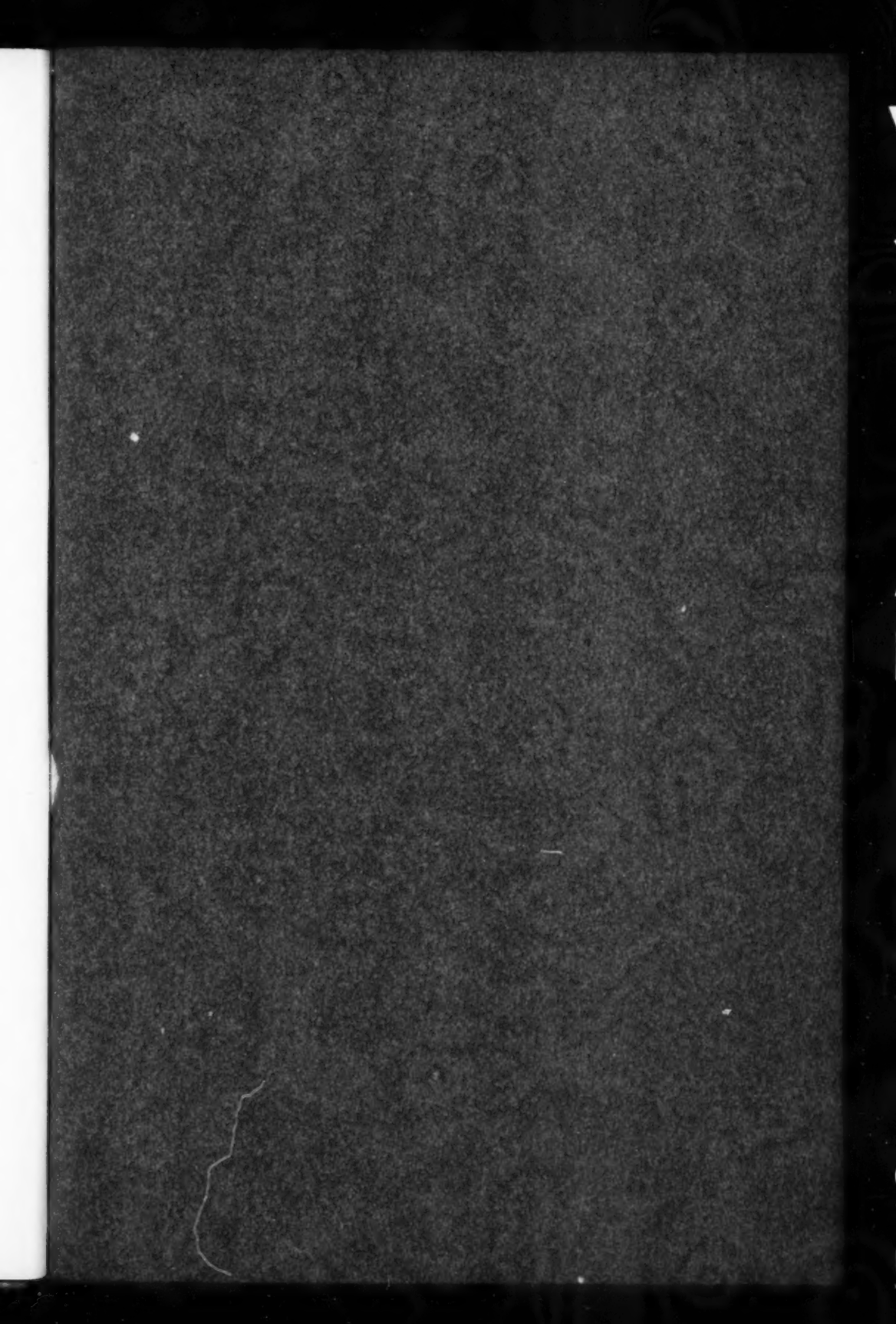
JANUARY, 1909

Temperature.—The first part of the month was marked by extremely cold weather in the Western Provinces and British Columbia, and the monthly mean temperature in that portion of Canada was from 1 to 15° below the average, the difference increasing westward from Manitoba. In Ontario, on the other hand, there was much unseasonably mild weather, as is evidenced by mean temperatures of from 2 to 6° above normal. More seasonable temperature conditions prevailed in Quebec and the Maritime Provinces, and the mean temperature there was in the close neighborhood of the normal value.

For the highest and lowest temperatures at various stations see the accompanying table.

Precipitation and Depth of Snow on Ground.—The precipitation was less than average over the greater portion of Canada, but in the St. Lawrence Valley and in New Brunswick it was somewhat in excess. The most marked feature, however, was the unusual snowfall in British Columbia where even near the coast there was sleighing on several days and the higher levels were soon thickly covered. At the close of the month in the Western Provinces the depth varied from a trace in Southern Alberta to 8 inches at Edmonton, 14 at Prince Albert, and about 6 inches over most of Manitoba. Ontario was snow covered, the depth ranging from about 2 inches in the south to 27 inches in the Ottawa Valley, and 21 inches in New Ontario. Quebec and Northern New Brunswick were buried under a depth of from 20 to 48 inches of snow, while the Maritime Provinces showed a white mantle varying from 5 to 28 inches in depth.

METEOROLOGICAL OFFICE,
TORONTO, CANADA,
February 1, 1909.

Temperatures for December and January

Station	December		January	
	Highest	Lowest	Highest	Lowest
Yukon				
Dawson	24	-48	14	-64
British Columbia				
Agassiz	56	20	50	- 4
Atlin	38	-26	26	-46
Barkerville	40	-22	46	-36
Kamloops	56	6	48	-29
New Westminster	48	22	50	2
Vancouver	50	24	51	4
Victoria	46	30	50	8
Western Provinces				
Banff	58	- 7	38	-47
Battleford	42	-28	24	-48
Calgary	47	-20	48	-42
Carberry	–	–		
Edmonton	44	-30	32	-50
Medicine Hat	48	-20	49	-40
Minnedosa	39	-30	41	-40
Moosejaw	44	-25	41	-42
Morden	43	-26	47	-41
Oak Bank	35	-26	36	-49
Portage la Prairie	36	-24	43	-40
Prince Albert	40	-38	24	-48
Qu'Appelle	40	-32	38	-46
Regina			39	-52
Swift Current	44	-25	44	-38
Winnipeg	34	-22	40	-45
Ontario				
Agincourt	40	- 2	50	- 6
Alton	54	-12	57	-15
Aurora	53	- 7	52	- 9
Bancroft	38	-26	40	-26
Beatrice	50	-18	42	-17
Birnam	40	4	60	-12
Bloomfield	50	1	48	- 9
Brantford	43	1	59	-20
Bruce Mines	38	-16	39	-19
Chatham	51	10	64	- 8
Clinton	58	- 5	59	- 9
Cottam	60	4	62	-13
Cockburn Island	51	6	41	-10
East Toronto	54	- 2	56	- 6
Gravenhurst	49	-14	43	-17
Haliburton	54	-26	41	-19
Hamilton	55	8		
Huntsville	37	-11	42	-17
Kenora	30	-25	38	-44
Kinmount	37	-23	39	-21
Kingston	52	- 6	41	- 9
Lakefield	56	-11	44	-10
London	42	2	61	-14
Lucknow	46	8	58	- 4
Meaford	58	9	58·0	1
Midland	46	6	58	-10
North Gower	–	–	44	
Otonabee	46	- 5	45	- 7
Ottawa	52	-13	40	-16
Owen Sound	41	- 6	49	- 3
Paris	54	- 2	60	-16
Parry Sound	40	- 6	45	-15
Peterboro'	55	-19	43	-10
Point Clark	41	13	45	2
Port Arthur	37	-16	41	-37
Port Burwell	44	8	46	-11
Port Dover	44	8	57	-14
Port Hope	53	- 3	46	- 7
Port Stanley	52	9	52	- 6
Rockliffe	43	-20	34	-25
Ronville	41	-20	46	-20
Sarnia	45	4	59	- 3
Southampton	47	2	57	- 6
Stony Creek	52	10	62	-13
Stratford	54	5	56	-10
Toronto	57	6	57	- 3
Uxbridge	39	-10	47	-11
Wallaceburg	57	5	60	4
Welland	52	7	54	-14
White River	32	6	34	-46
Windsor	60	9	60	
Quebec				
Brome	52	-23	44	-30
Father Point	40	16	38	-23
Montreal	52	8	42	-17
Quebec	44	-14	38	-23
Sherbrooke	53	-17	44	-26
Maritime Provinces				
Charlottetown	46	- 2	49	-12
Chatham	44	-17	52	-22
Fredericton	48	-20	49	-27
Halifax	54	5	53	9
Moncton	51	-10	56	-20
St. John	50	- 4	53	10
St. Stephen	58	-10	53	-13
Sussex	57	-14	56	-19
Sydney	53	-12	54	- 4
Yarmouth	52	6	52	4